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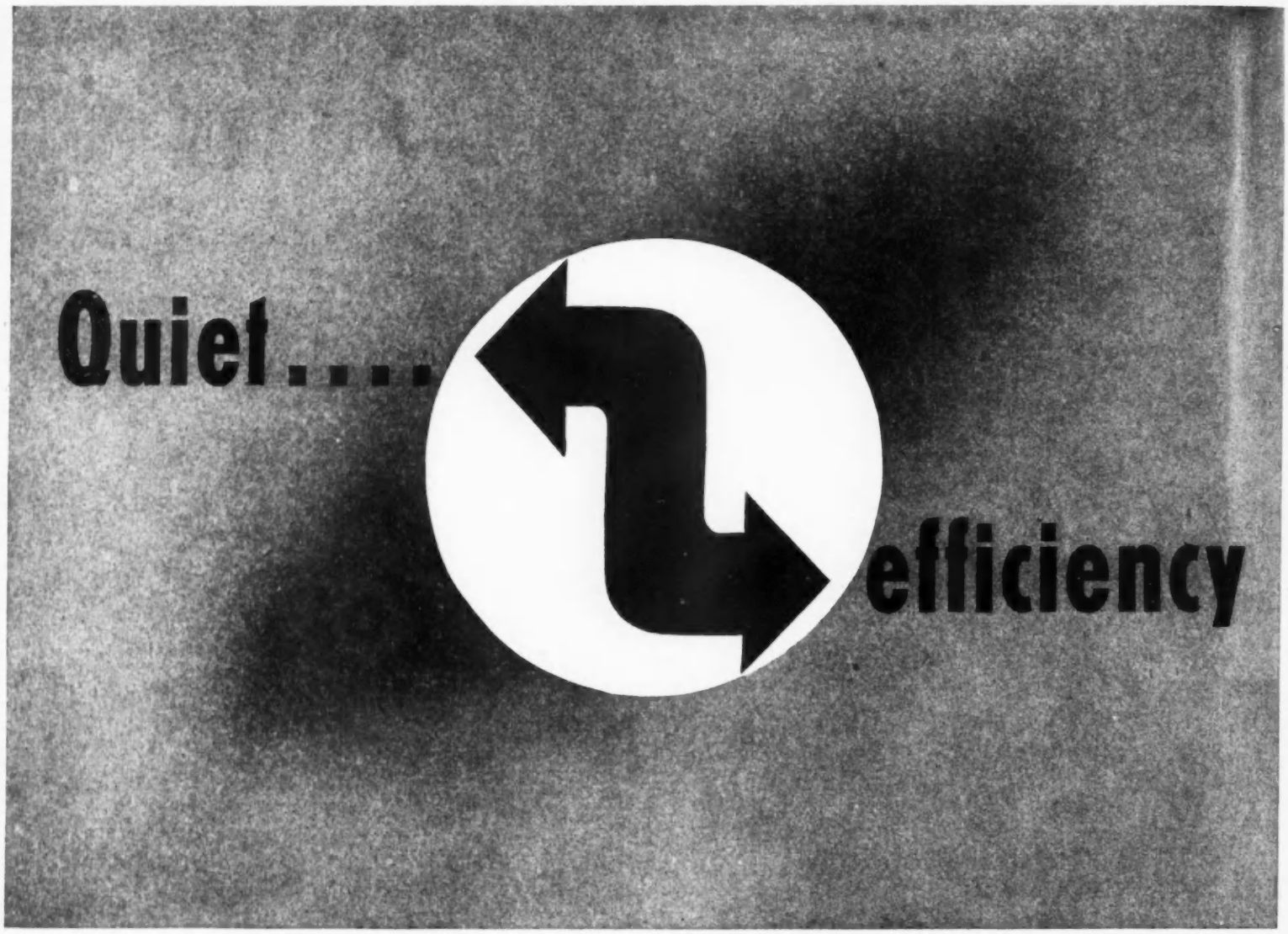

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EXHAUST-PIPE PRESSURE WAVES.

By L. J. KASTNER, M.A.

IT has been known for some considerable time past that in certain circumstances the discharge of the exhaust gases from an engine cylinder may give rise to a vacuum which can be employed for improving the scavenge of the engine. Until recently, however, the general opinion appears to have been that attempts to employ this vacuum were unlikely to prove successful in practice; but it now seems probable that this view was based on an insufficient understanding of the phenomena involved. Although of late engines employing directly the energy of the exhaust discharge for increasing the air consumption of the cylinders have achieved considerable prominence, yet even now it must be admitted that the mechanism underlying the production of a vacuum due to the egress of the exhaust gases is not fully understood.

It appears, however, that two distinct phenomena are responsible for this vacuum; firstly, a sufficiently sudden discharge from the cylinder itself may give rise to a transitory fall of pressure below atmospheric and, secondly, a periodic wave may be formed in the engine exhaust pipe, fluctuating between positive and negative values of pressure. In the former case, the magnitude of the depression will be controlled to a certain extent by the ratio of the area of the port to the cross-sectional area of the cylinder, and to a certain extent also by the rapidity with which the port is opened. In the latter case, the amplitude of the depression will depend on a number of factors, but the most important of these will be the dimensions of the exhaust pipe itself. It will be clear, however, that the effectiveness of the depression in increasing the air consumption depends not only on its maximum amplitude but also upon its absolute duration and upon the instant at which the pressure first falls below atmospheric. Where pressure waves in an exhaust pipe are concerned, these two latter factors are governed absolutely by the length of the pipe; if no pipe is present, the vacuum consequent on any sudden discharge must be of exceedingly short duration.

In the present article, the writer will confine himself entirely to a discussion of the production of pressure waves in the engine exhaust system, and will make no attempt to analyse conditions in the cylinder due to the sudden discharge of gases therefrom. As a starting point it will be useful to give a very brief account of the method of production of pressure waves in an exhaust pipe, before examining the process in detail. Pressure waves in the engine exhaust pipe are excited in the first place as the result of the opening of the exhaust orifice, and the consequent production of a pressure pulse at the port. This pulse will start the gases in the pipe vibrating with a frequency dependent on the dimensions of the pipe, and on the temperature of the gases themselves. The process of wave formation depends on the production of reflections of the original pulse from either end of the pipe, and the time interval between each successive reflection, which has a great influence on the shape of the final net pressure wave, is governed by the time taken by a pulse to travel from the exhaust orifice to the far end of the exhaust pipe and back again. Hence, a knowledge of the appropriate velocity of propagation is necessary.

Velocity of Propagation of Waves in the Exhaust Pipe.—The velocity of propagation of pressure waves in a pipe will, in general, be somewhat less than the corresponding velocity of propagation in free air at the same temperature. The following factors can be shown theoretically to have influence in lowering the velocity of propagation in the pipe as compared with that in free air: (1) Conduction of heat from the pipe. (2) Yielding of the wall of the pipe. (3) Internal friction. (4) The frequency of the vibration in the pipe. According to Kirchhoff, the velocity of propagation of pressure waves in a pipe is given by the equation

$$u = a\left(1 - \frac{\gamma}{d\sqrt{\pi n}}\right) \quad . \quad . \quad (1)$$

where a represents the velocity of sound in free air at a temperature equal to that of the contents of the pipe, d is the diameter of the pipe, n is the frequency of the vibration, and γ is a factor depending on the friction and heat conductivity of the gas in the pipe. The above formula is, strictly speaking, only applicable to vibrations of small amplitude, and neglects any losses due to the yielding of the pipe walls, radiation, etc. Moreover, there is reason to believe that the importance of the wave frequency is exaggerated. Nevertheless, it can be very useful in indicating the range over which the mean velocities of propagation in an exhaust pipe can vary under average conditions.

The factor γ is calculated from the expression

$$\gamma = \sqrt{\frac{\mu}{\rho}} + \left(\sqrt{\frac{K_p}{K_v}} - \sqrt{\frac{K_v}{K_p}}\right)\sqrt{\frac{G}{\rho K_v}} \quad (2)$$

in which μ and ρ refer to viscosity and density respectively, K_p and K_v are the specific heats at constant pressure and constant volume, and G is the coefficient of conductivity of the gas. For air at atmospheric pressure, the appropriate values of γ are given in Table I, to cover a range of temperatures from 100 deg. C. to 250 deg. C. As regards the appropriate value of a to be substituted in equation (1), this must be calculated for a temperature equal to that of the mean temperature in the pipe, thus, if t is the mean temperature in deg. C., then

$$a = 1{,}089\sqrt{1 + \frac{t}{273}} \text{ ft. per second.}$$

The values for the required temperature range are given in Table II.

TABLE I.—*Values of γ for Air.*

Temperature. Deg. C.	γ In. × Sec.$^{-1}$
100	0·2775
150	0·307
200	0·338
250	0·366

Since the values of γ and a are now known, u, the velocity of propagation in the pipe, can be calculated for any desired pipe diameter and wave frequency. The calculation has been performed for pipe diameters varying from 1 in. to 4 in., at a chosen frequency of 75 c.p.s., and the results are shown plotted in Fig. 1. It will be noted that, over the range of temperatures explored, the variation of velocity of propagation with pipe diameter is relatively small, though the variation increases somewhat as the temperature increases.

It has already been mentioned that the Kirchhoff equation cannot strictly be applied to vibrations of large amplitude, such as are present in exhaust pipes. Owing to the greater amplitude of these exhaust pipe waves, the energy losses from the pipe are increased, and the velocity of propagation will be less, and will fall off at a somewhat greater rate as the pipe diameter is reduced. However, in any practical case it would be too much to expect to calculate an exact value of the velocity of propagation, as the value of the mean temperature of the gases in the exhaust pipe is only known approximately. For instance, we may consider the cases of a high-speed engine with a relatively short exhaust pipe, and a low-speed engine with a long exhaust pipe. In the former case, the mean velocity of propagation of the waves in the pipe will be high, as the gases in the pipe will not have much time to fall in temperature before they are ejected; but in the latter, the mean temperature will be lower, resulting in a decrease in the velocity of propagation.

TABLE II.—*Values of a for Air.*

Temperature, Deg. C.	a, Ft. per Sec.
100	1,272
150	1,353
200	1,430
250	1,502

One further point concerning the propagation of pressure waves of high amplitude must be mentioned. When such waves are concerned, the velocity of propagation relative to the undisturbed medium can be shown to depend on the condensation,

$$S = \frac{\partial \rho}{\rho},$$

and is given by Lamb* as

$$u^1 = u\,(1 + S)^{\frac{1}{2}(\gamma + 1)},$$

where u has the same meaning as before. Hence, a wave of large amplitude may initially have a velocity considerably greater than the ordinary velocity of sound, and velocities of more than 600 m. per second have been recorded near the source of the initial disturbance. It is important to note, however, that such high velocities are very rapidly reduced to the normal value as the wave travels away from the origin. Consequently, although very high velocities may occur in the early stages of the process, these have but little influence on the *average* velocity of propagation. Unfortu-

* H. Lamb, *Dynamical Theory of Sound*, chap. VI, para. 63.

Fig. 1.

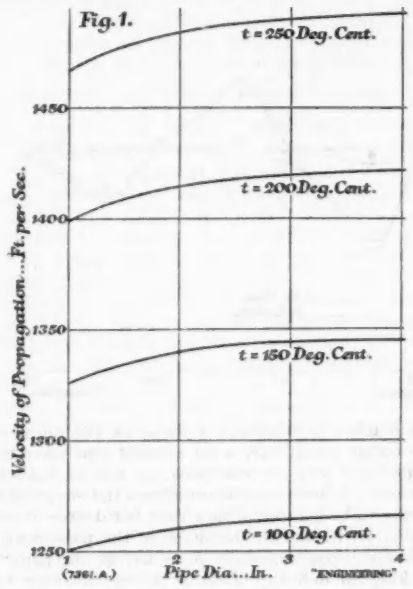


Fig. 2.

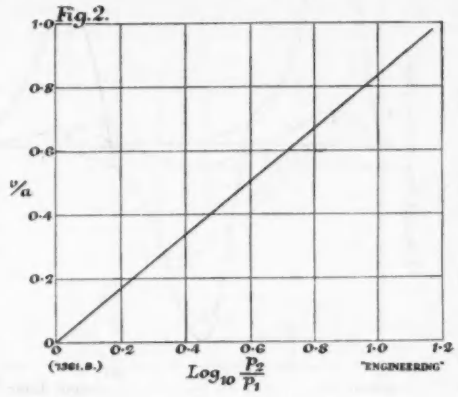
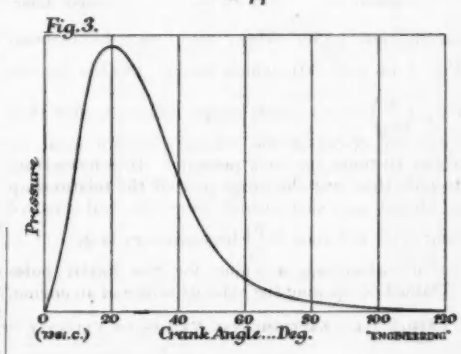


Fig. 3.



nately, there are very little experimental data available regarding measured velocities of propagation obtained from exhaust-pipe pressure waves, but it is hoped that the figures of Table III, though few in number, are sufficient to indicate the way in which the mean velocities of propagation may be expected to vary. The low values obtained from the slow-running two-stroke engines are to be expected in view of the long exhaust pipes with which these engines were fitted. Mucklow's figures were obtained on a motored engine, and correspond to a mean exhaust-pipe temperature of some 20 deg. C. only.

The Initial Pulse.—In considering the possibilities of obtaining calculated values for the wave form and amplitude of the initial pulse produced in the exhaust pipe on opening the exhaust orifice, it will be necessary first of all to examine conditions due to a sudden release of pressure, such as would be experienced on the instantaneous removal of a partition, separating a region of higher pressure from one of lower pressure. The examination must include an investigation into the velocity of propagation of the pulse of compression propagated into the region of initially low pressure, as well as of the maximum value of the velocity of flow of the gases released from the high-pressure region. Studies of transitory phenomena of this type are, unfortunately, rather rare, but in the present instance the analysis given by Kobes* may be applied to the problem under consideration.

Consider a long cylindrical pipe of uniform section divided into two parts by a partition on one side of which exists a higher pressure p_2, and on the other a lower pressure p_1. If the partition is suddenly removed, there is set up a compression pulse which travels into the region of lower pressure with a velocity of propagation c^1, while at the same time a rarefaction pulse is induced which travels in the opposite direction. An equalisation pressure p is built up between p_2 and p_1, and a gas velocity v is generated due to the fall of pressure. We may first of all examine the rarefaction pulse. Considering a pressure pulse propagated with a velocity u_p, the equation of motion takes the form, for a small change,

$$d\,p = \frac{\rho\, u_p\, v}{g},$$

ρ referring to density, so that for the rarefaction pulse

$$v = \int_p^{p_2} \frac{g\,d\,p}{u_p\,\rho},$$

and if an adiabatic change of state is assumed

$$v = \sqrt{\frac{g\,p_2^{\frac{1}{\gamma}}\,V_2}{\gamma}} \int_p^{p_2} \frac{d\,p}{p^{\frac{1+\gamma}{2\gamma}}} = \frac{2\,a}{\gamma - 1}\left[1 - \left(\frac{p}{p_2}\right)^{\frac{\gamma-1}{2\gamma}}\right] \quad . \quad . \quad . \quad . \quad (3)$$

if

$$a = \sqrt{g\,\gamma\,P_2\,V_2}.$$

For the compression pulse we may write

$$p - p_1 = c^1\,v\,\rho,$$

or

$$\frac{p}{p_1} = 1 + \frac{c^1\,v}{a^2}\,\gamma \quad . \quad . \quad . \quad . \quad (4)$$

By writing down the equations for the work done in compression and in setting the gas in motion a value of c^1, the velocity of propagation of the compression pulse, can be found. This gives

$$c^1 = \frac{\gamma+1}{4}\,.\,v\,. + \sqrt{\left(\frac{\gamma+1}{4}\right)^2\,.\,v^2 + a^2}. \quad . \quad (5)$$

The equations (3), (4) and (5) enable us to find a value for the velocity of flow v for any given values of p_2 and p_1. From equations (3) and (4), we have

$$\left(\frac{p_1}{p_2}\right) = \frac{\left(1 - \frac{\gamma-1}{2\,a}\,.\,v\,.\right)^{\frac{2\,\gamma}{\gamma-1}}}{1 + \frac{\gamma\,v\,c^1}{a^2}}.$$

* *Z. Öst. Ing. u. Arch. Vereis*, Bd. 62, 1910, page 553.

Substituting for c^1 from equation (5) and taking $\gamma = 1{\cdot}4$, this takes the form

$$\left(\frac{p_1}{p_2}\right) = \frac{(1 - 0{\cdot}2\,z)^7}{1 + 0{\cdot}84\,z^2 + z\,\sqrt{0{\cdot}7056\,z^2 + 1{\cdot}96}} \quad . \quad (6)$$

if $z = \frac{v}{a}$.

From this expression it will be seen that, when $\frac{p_2}{p_1} = \infty$, $v_{max} = 5a$, and using this value in equation (5), we obtain $c^1_{max} = 6{\cdot}16a$. Hence, it appears that in certain circumstances extremely high values are to be expected for the velocity of flow, and for the velocity of propagation of the compression pulse, but these circumstances require such very high release pressures that, in internal-combustion engine work, they may be ignored. Fig. 2, on page 301, which shows $\frac{v}{a}$ plotted against $\log_{10}\left(\frac{p_2}{p_1}\right)$ over a small range, makes it clear that for v to exceed a the release pressure must be about 16 times the back pressure. It is interesting to note that over the range plotted the relationship is almost an exact straight-line one, but this, of course, is not true if $\frac{p_2}{p_1}$ becomes very large.

For calculating a value for the initial pulse obtained on opening the exhaust orifice of an engine, or for finding instantaneous values of the velocity of flow of the gases at the entrance to the exhaust pipe, the equations (3), (4) and (5) are useful. In any real case, an indicator diagram is necessary to give the rate of fall of pressure in the cylinder during the early stages of the exhaust process, so that p_2 may be obtained; p_1 may be taken as atmospheric and a will apply to the conditions in the cylinder over the interval considered, during which the temperature may be estimated with sufficient accuracy. Where four-stroke working is in question, the pressure pulse produced by the engine piston in accelerating the waste gases through the exhaust orifice is of considerable importance, and must be calculated independently and superposed on the pulse due to the sudden discharge. The calculation of the piston pulse, though tedious, is not unduly difficult.

In practice, a number of factors enter into the problem which have not so far been mentioned. Firstly, the compression pulse in the pipe will not rise instantaneously to its maximum value, since the exhaust orifice opens at a finite rate, and, even in the case of the two-stroke engine, the piston motion—usually ignored—will have some influence at this early stage. Secondly, although the piston pulse itself is closely similar in shape at all rotational speeds and only varies in amplitude, the pulse due to the sudden discharge is to some extent dependent on absolute time. Hence, such factors as rate of opening of exhaust orifice, coefficient of discharge, ratio of area of orifice to piston area, ratio of pipe diameter to cylinder volume, etc., will all exert some influence.

It must be admitted that a calculation of the initial pulse, using the methods outlined above, will be laborious, and in the writer's view the results obtained will not repay the trouble involved. A very much quicker and more satisfactory procedure in practice is to assume a shape for the pulse, and to obtain graphically a net exhaust-pipe wave from this pulse and its reflections, as will be explained below. A little experience allows the shape of the pulse to be guessed with a very fair degree of accuracy, or, if desired, the shape of the pulse may be obtained experimentally from any given engine by taking an indicator diagram at the entrance to a long exhaust pipe, the pipe being drilled with holes at frequent intervals so as to damp out the reflections of the pulse. It will be clear that a knowledge of the absolute amplitude of the pulse is of no importance, since it is only necessary to know the wave form, and not the absolute amplitude, of the exhaust-pipe pressure wave when use is to be made of it for improving the charging of the cylinder. Fig. 3, page 301, represents a typical shape for a pressure pulse which has been found useful in synthesising two-stroke engine exhaust-pipe waves. For use with four-stroke engines, the pulse must be modified by the addition of the calculated pressure pulse due to the piston movement, appropriate to the engine speed considered, and as a first approximation, the amplitude of the latter pulse may be assumed to be half that of the former.

Fig. 4.

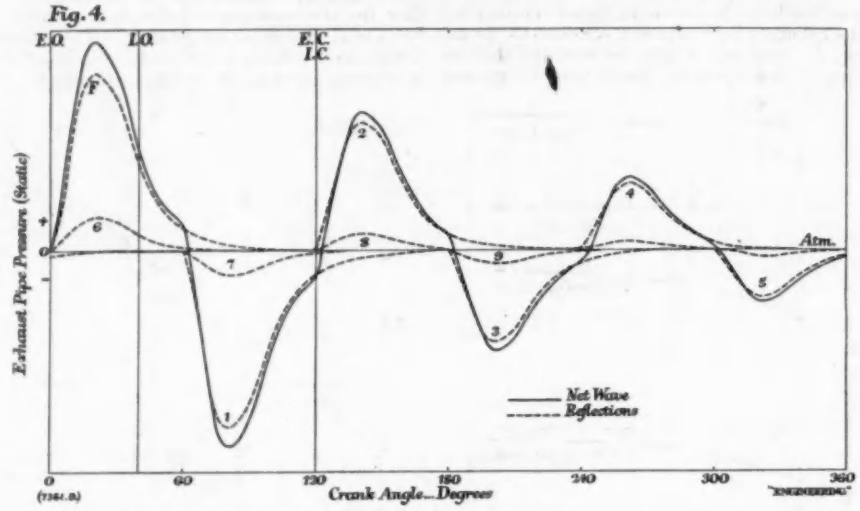


TABLE III.—Experimental Values of Velocity of Propagation of Exhaust-Pipe Waves.

Reference.	Authority.	Engine.	Exhaust Pipe diameter. in.	Mean Velocity, ft. per second.
Proc. I.A.E., Vol. 27, page 614	Morrison	Four-stroke	1·625	1,350
Proc. I.Mech.E., Vol. 138, page 367	Farmer	Two-stroke, 750 r.p.m.	2·5	1,260
Forschung, V.D.I., Bd. 5, page 226	Schmidt	" " 370 r.p.m.	5·35	1,260
Forschung, V.D.I., Bd. 6, page 280	Pischinger	" " 145 r.p.m.	8·85	1,230
Proc. I.Mech.E., Vol. 143, No. 2, page 109	Mucklow	Four-stroke, 1,600 r.p.m. (motored engine)	2·875	1,100

Formation of Pressure Wave in Exhaust Pipe.—Assuming a knowledge of the form of the pressure pulse, and of its mean velocity of propagation in the pipe, attention can be given to the method of formation of the net pressure wave which is produced by a summation of the reflections from either end of the pipe. At a time $\frac{L}{u}$ seconds after the exhaust orifice has opened, the pulse will have arrived at the open end of the exhaust pipe of length L ft., supposing the mean velocity of propa-

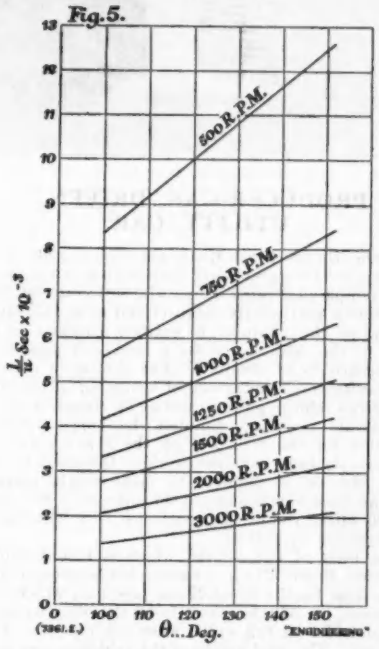
gation to be u. At the open end of the pipe, the pulse will suffer reflection with change of sign, and will return to its starting point. The amplitude of this reflection will be less than that of the original pulse, since the open-end reflection coefficient K is less than 1. Immediately on arrival, the reflection referred to will itself be reflected, this time without further change of sign (closed-end reflection) and its amplitude will be again reduced, since also the closed-end reflection coefficient K^1 is less than 1. Hence, at a time $\frac{2L}{u}$ seconds after the exhaust orifice has opened, there will be present at that end of the pipe adjacent to the orifice a double reflection of amplitude $(K + K K^1)$ times the amplitude of the original pulse, but opposite in sign.*

This first double reflection will now travel towards the open end of the pipe, will be reflected there with change of sign, and will return to the closed end after a further interval of $\frac{2L}{u}$ seconds, forming a second double reflection of amplitude $K K^1$ times that of the first, and the process will proceed with the formation of further double reflections each of amplitude $K K^1$ times that of its predecessor, of opposite sign, and $\frac{2L}{u}$ seconds later in phase. The algebraic sum of these reflections will produce a pressure wave in the pipe.

The simple argument outlined above takes no account of the abnormally high losses which may be expected to occur during the first transit. During this time, the particle velocities of the exhaust gases in the pipe are high, and the gases tend to be driven out of the pipe in the form of a jet. Reflection thus probably occurs outside the end of the pipe proper, and during this period the open-end reflection coefficient K assumes a lower value than is normal. Thus, the first double reflection is of unexpectedly low amplitude; and will probably be of the same order of amplitude as the initial pulse itself. Under average conditions, assuming a straight exhaust pipe of uniform section, the values $K = 0{\cdot}8$, and $K^1 = 0{\cdot}9$ may be accepted, with the proviso that the pulse undergoes such heavy damping during the first transit that the value of the factor $(K + K K^1)$ appropriate to this transit only attains some 60 per cent. of its apparent value. If the pipe is not of uniform cross section, but has a divergent taper, the proportion of energy transmitted at the open end will be increased, and the damping of the reflections will be heavier than for the case of a uniform pipe.

Fig. 4, opposite, is a graphical illustration of the process of synthesising an exhaust-pipe pressure wave. The engine to which the treatment is applied is to be a single-cylinder, two-stroke, the exhaust orifice of which opens 40 deg. before the inlet orifice. The total opening period of the exhaust orifice is to be 120 deg. crank angle, and that of the inlet orifice 80 deg., so that both close at the same time. The exhaust pipe length is to be so chosen that the ratio $\frac{12NL}{u} = 60$ deg., where N is the engine speed in revolutions per minute; L is the exhaust-pipe length, the pipe being assumed to be of uniform cross section, and u is the velocity of propagation appropriate to the mean temperature of the gases in the exhaust pipe. The graphical treatment is relatively simple. The first step is to sketch in the initial pulse, which may be an assumed shape—actually the shape given in Fig. 3 is used here. This pulse is marked F in Fig. 4. The first double reflection is now drawn in, opposite in sign to the initial pulse, of equal amplitude, and commencing $\frac{2L}{u}$ sec. $= \frac{12NL}{u}$ deg. $= 60$ deg. later. This is marked 1 on the diagram. The second double reflection now follows. This is opposite in sign and of $K K^1 = 0{\cdot}8 \times 0{\cdot}9 = 0{\cdot}72$ times the amplitude of the first double reflection. It commences $\frac{4L}{u}$ sec. after E.O. The third double reflection is of $0{\cdot}72 \times 0{\cdot}72 = 0{\cdot}52$ times the amplitude of the first double reflection and commences $\frac{6L}{u}$ sec. $=$ 180 deg. after E.O.; and so on for the succeeding reflections. The reflections 6, 7, 8 and 9 form the residual wave, which is here in phase with the main wave, and may or may not be of importance according to the degree of damping in the exhaust system. The full line in Fig. 4 is the algebraic sum of all the reflections and represents the net exhaust-pipe pressure wave. It will be observed that the synthetic wave shows a useful vacuum during a considerable proportion of the time when both the inlet and exhaust ports are open, so that conditions are favourable for thorough scavenging of the engine cylinder. If the pipe length had been so chosen that the ratio $\frac{12NL}{u}$ were much greater than 60 deg., then the vacuum period would have arrived too late to improve the scavenge, and, conversely, if $\frac{12NL}{u}$ were much less than 60 deg., there would have been a series of fluctuations between positive and negative values of pressure during the period when both ports were open, and these could only have had an unfavourable effect.

Fig. 5.



As a general rule it may be said that the process of obtaining synthetic exhaust-pipe waves for a proposed design is well worth the small amount of trouble involved, in that it gives a most useful guide to the probable form of the pressure fluctuations with any given valve timing, and, moreover, provides a powerful method for examining the effects of "stepped" pipes, and other devices for prolonging the vacuum period. It will have been observed that the conditions for which Fig. 4 applies involve the use of an exhaust pipe, the natural period of which, expressed in degrees crank angle, is equal to the total opening period of the exhaust ports, that is to say

$$24 \frac{NL}{u} = \theta,$$

where θ is the total opening period referred to. In practice, it will be found that a pipe of this natural wavelength will enable the exhaust-pipe vacuum period to be utilised to very good advantage, where two-stroke working is concerned, and the consequent improvement in performance will be maintained for a considerable speed range on either side of the best speed given by N. Although a valve timing of the type shown in Fig. 4 will be the most satisfactory for the proper employment of the exhaust-pipe vacuum, since the exhaust-pipe wave reaches its maximum positive amplitude before the inlet ports open, yet at the same time the vacuum period can be distinctly valuable even when the exhaust and inlet ports are entirely controlled by the engine piston, and the points E.O., I.O., I.C., E.C., are symmetrically disposed about the bottom dead centre. Under the latter conditions, also, the natural wavelength of the exhaust pipe should be chosen as explained above.

Figs. 1 and 5 will be found of value in estimating a suitable exhaust-pipe length for a two-stroke engine. The method of using these is as follows: The abscissæ of Fig. 5 represent various values of the duration θ. From the value of θ appropriate to the engine under consideration, a perpendicular is drawn to cut the line representing the speed at which the engine is to run. From the point of intersection a line is drawn perpendicular to the y-axis. The intersection of this line with the y-axis will give the appropriate value of the fraction $\frac{L}{u}$. An estimate is now made of the mean temperature of the gases in the exhaust pipe, and this, together with a knowledge of the pipe diameter, will enable a value for the average velocity of propagation in the pipe to be obtained from Fig. 1. An example will make this clear: Consider a two-stroke engine, to run at 1,000 r.p.m. The total period over which the exhaust ports are open is 120 deg. crank angle, the exhaust pipe diameter is 2 in., and the mean temperature of the gases in the exhaust pipe is 150 deg. C. From Fig. 5, for $\theta = 120$ deg. and $N = 1{,}000$ r.p.m., the value of $\frac{L}{u} = 5 \times 10^{-3}$ sec. From Fig. 1, for $t = 150$ deg. C. and $D = 2$ in., the value of $u = 1{,}340$ ft. per second. Hence the correct exhaust-pipe length $L = 5 \times 10^{-3} \times 1{,}340 = 6{\cdot}7$ ft. approx. If this length is inconveniently short, an expansion chamber of ample size can be fitted at the end of it, so that the tail pipe shall have no effect on the frequency of the vibrations. The appropriate value of the temperature t is then to be taken as the mean temperature of the gases in the pipe leading from the exhaust ports to the expansion chamber.

Although the rules given above apply to two-stroke working only, a useful gain can also be expected from a correct use of the exhaust-pipe vacuum where four-stroke engines are concerned. In the latter case, however, the governing conditions are, as a rule, more complicated owing to the wide variations in valve timing which are possible. Where the valve timing is fixed, simple rules can again be formulated for a correct choice of exhaust-pipe length, but if full benefit is to be obtained, a valve timing somewhat different from the normal is required. Synthesis of the exhaust waves can again be most useful here, bearing in mind that the initial pulse will not be of the same form as for the two-stroke, owing to the importance of the piston movement.

In a brief article it is clearly impossible to do more than indicate the nature of exhaust-pipe waves, to give some idea of the factors governing wave form and frequency, and to suggest how such waves may be usefully employed. A calculation of the absolute amplitude of the wave at any instant is difficult and laborious, and the results obtained do not repay the trouble involved, since all that is required in practice is a knowledge of the approximate wave form and frequency in relation to the valve timing.

* The attenuation of the pulse as it travels up and down the pipe has been neglected here, as reductions of amplitude from this cause will, in general, be small. Note that this is not the same as making the—quite incorrect—assumption that the amplitude of the net pressure wave is constant at all points along the pipe.

INSTITUTE OF PETROLEUM.—The Council of the Institute of Petroleum has awarded the Students' Medal and Prize to Mr. T. Y. Ju, of Birmingham University, for an essay on "Behaviour of Fuels in Compression-Ignition Engines." A special prize has also been awarded to Mr. D. G. Brunner, of Birmingham University, for an essay on "Mud Fluids for Drilling." Messrs. B. A. Murphy, of Melbourne, and P. G. Owen, of Birmingham University, have been highly commended for their essays.

PARIS-MARSEILLES RAIL SERVICE.—It is reported in *Modern Transport* that railway communication between Paris and Marseilles has been re-established. The iron bridge over the River Isère, 10 km. north of Valence, destroyed during the German advance, on June 24, has been rebuilt, and the first train direct from Paris to Troyes, Lyons, and Marseilles crossed the bridge at a speed of 20 miles per hour. Subsequently the speed of following trains was increased to 40 miles per hour, and ater normal running was resumed.

LITERATURE.

Air Photography Applied to Surveying. By C. A. Hart, M.Sc. London: Longmans, Green and Company. [Price 25s.]

The application of air photography to surveying is a subject which has not received much attention in the survey schools of Great Britain. An interesting map on page 3 of this book suggests a reason, for it indicates that the work of the Ordnance Survey Department is, on the whole, far in advance of similar work in other countries; on this account, there is less urge to adopt new methods requiring considerable initial outlay and there is a corresponding disinclination to introduce the subject into the schools. From this map and the relevant text it appears that, while the whole of Great Britain has been surveyed to a large scale and published maps are readily obtainable, surveys to a scale of 1/25,000 have only been carried out in Europe over Denmark, Holland, parts of Germany and Italy, and some other scattered areas, while even to a scale of 1/100,000 the work is practically limited to western Europe and Scandinavia; moreover, many of these maps are only available for reference in manuscript form. Large areas in America have been mapped to a 1/100,000 scale, but the need for extensive original work has helped to make the rapid methods of aerial survey popular on that continent. The use of aerial surveying has not been entirely neglected in Great Britain, but, as may be expected, it is in the Dominions that it has found more favour; within the British Empire as a whole our instrument makers, surveyors, airmen, and writers have had a fair share in the world development of this art, since it received its first real stimulus in the war of 1914-1918.

The book falls roughly into two sections. The first three chapters deal with historical development and put forward a case for the use of aerial photography; the remaining chapters give a detailed description of theory and practice. It is easier to read the first three chapters after a perusal of the latter half of the work for there are unfamiliar terms which will be better understood when the theory has been roughly mastered. This new branch of surveying calls for intensive studies of perspective and stereoscopy which will add very considerably to the present survey courses. It also demands the use of apparatus with which the ordinary survey draughtsman is unfamiliar—some of it too expensive to be available except in offices organised for extensive work. The chapters on stereoscopic work are very well done. In a very interesting chapter, the author indicates the value of aerial survey in solving engineering and ecological problems. They show up details which would escape the attention of the ground surveyor, such as differences of tone which indicate facts of geological, archæological and economic interest. The right interpretation of the photographs demands much study and experience, but the results which can be obtained give reason for expecting a very considerable development in the use of aerial surveys once authorities realise their value. The author comments also on the fact that British technicians tend to concentrate on improving the accuracy of field work in order to simplify office routine, while the continental trend has been rather to accept rougher methods in the field with consequent need for intricate office apparatus and greater labour in the interpretation of the work. This may be due in part to local needs, but it seems to correspond with a difference in outlook and psychology which manifests itself in other ways.

The surveyor trained only in ground work may view with some distrust, not unmixed with fear, this intrusion of new methods into his preserves. He will be reassured, for the book indicates quite clearly that ground surveying is an inseparable complement to the work of the aerial photographer. A difficult post-war problem will be to find suitable occupation for the men who are to-day doing such magnificent work in the Royal Air Force. Air surveying may furnish at least one outlet, demanding just that skill in accurate flying which is being demonstrated daily over Hamm and elsewhere. The production of this volume is decidedly opportune.

PRODUCER-GAS DRIVEN UTILITY CAR.

PRODUCER-GAS DRIVEN UTILITY CAR.

Although the Brush-Koela gas producer for motor vehicles has been previously dealt with in our columns, the example illustrated above will be of interest, as it embodies a particularly compact and accessible layout which, as the producer is entirely enclosed in the body of the vehicle, enables a neat and presentable appearance to be obtained. The vehicle in question is a utility car, forming one of a number of producer-gas driven vehicles put into service by Messrs. Northern Aluminium Company, Limited, Banbury, and it is intended for the transport of the firm's executives between its three different works. Occupied in such duty, the car is required to make single journeys ranging from a minimum of 45 miles to a maximum of 100 miles, conditions which are very suitable for producer-gas operation.

The body of the vehicle, which is mounted on a standard Morris 25-h.p. chassis, has a compartment at the rear for the Brush-Koela producer, which compartment, as will be clear from the illustration, is accessible for its full width when the two rear doors are open. The total weight of the vehicle is just under 2 tons. The performance on tests has proved to be highly satisfactory. When "Suncole" is used as fuel, one filling of the hopper is sufficient for a range of approximately 100 miles, and we are informed that speeds of 40 m.p.h. to 50 m.p.h. can be maintained comfortably on average unrestricted roads, the maximum speed on the level being over 55 m.p.h. Starting, it is stated, is particularly easy with normal stopping periods; in exceptional circumstances, a start can be made on petrol, this being done on one occasion, when the car had been standing for 3½ hours, without re-lighting the producer.

As regards the layout of the producer and accessories, reference may be made to the sectional views given in Engineering, vol. 149, page 532 (1940). In the accompanying illustration the producer, with the hopper above it, is seen at the left hand. The horizontal drum on the right hand is the first-stage scrubber through which the producer gas is first passed in order to remove the major portion of its solid impurities and to lower its temperature. The scrubber should be opened for removal of the entrapped dust, etc., every 200 miles. From the scrubber, the gas passes successively through the two drum purifiers suspended from the roof. The first of these purifiers, i.e., that at the extreme right, contains water. In it such injurious constituents as silica, sulphuric acid, sulphur trioxide, and ammonia are removed, together with any remaining solid particles. The other purifier contains oil, and the sulphurous acid which is not absorbed by the water is removed by ferric chloride. The oil purifier also provides a certain amount of cylinder lubrication. Renewal of the water and oil charges after every 1,000 miles running is recommended.

All parts of the plant are readily accessible for easy operation and maintenance; thus, the valve for changing from cross-draught to up-draught in the producer is operated by cable from the driver's seat. The gas tube from the producer is formed in a large loop under the car in order to assist cooling. The radiated heat from the plant is successfully dissipated by the ventilating arrangements adopted. The floor of the producer compartment is formed of heavy wire mesh and there are hinged windows, opening forward, at the sides. The result is that when the car is moving a strong draught is induced through the compartment, the heated air escaping through sliding windows and a large louvred opening in the rear doors. The compartment is lined throughout by an insulating layer of asbestos covered with sheet metal. The body of the vehicle was supplied by Messrs. Hartwells, Limited, Oxford, who, as local agents for Messrs. Brush Electrical Engineering Company, Limited, Loughborough, also installed the producer.

TRADE MARKS IN EGYPT.

An official notice has been issued in Cairo, drawing attention to certain provisions of the new Egyptian Trade Marks Act of 1939, and more especially to the intention to institute legal proceedings against persons using the term "registered trade mark" in connection with any trade mark which has not been registered in accordance with the rules of that Act. Registration effected abroad will not justify the use of such a term; neither will the fact that a trade mark has already been deposited with the Bureau of the Mixed Court of Appeal be a legal defence of such use. Section 34 prescribes a penalty of imprisonment for a period not exceeding one year, and a fine not exceeding £E.100, or either of these penalties, for wrongfully indicating on trade marks or on business papers that registration has been effected. Further, the notice requests all traders, importers and manufacturers to abstain from offering for sale any goods bearing trade marks wrongfully indicating that the marks have been registered, and states that instructions have been given to the inspectors of the Department of Commercial Legislation and Industrial Property to institute proceedings against offenders.

The regulations also provide that any description of goods, on invoices, publicity matter or other documents, must "correspond completely and absolutely with the true facts." When the quantity, measure, gauge, weight, origin or component parts of a product constitute an element of its value, the importation, sale or exhibition of such products may be prohibited unless one or more of the details are indicated thereon, in a manner which will be laid down by Order. These indications must be written in Arabic.

Campbell Memorial Lecture.—Dr. S. L. Hoyt, of the Battelle Memorial Institute, Columbus, Ohio, U.S.A., has been selected to deliver the Edward De Mille Campbell Memorial Lecture for 1940, on October 23, at the annual National Metal Congress and Exposition, at Cleveland. His lecture will deal with modern metallurgy.

REGENERATIVE WORKING ON THE SOUTH AFRICAN RAILWAYS.

THE Pietermaritzburg-Glencoe single-line section of the main railway between Durban and Johannesburg, South Africa, was converted to electric traction in 1924, as the steep gradients and sharp curves by which it is distinguished were causing considerable delay to the coal and other important traffic. The necessary electrical energy was obtained from a power station at Colenso, about half-way along the electrified section, and from this, three-phase current was transmitted at 88 kV by twin lines to a number of substations. These substations were equipped with motor-generator sets, which supplied direct current at 3,000 volts to trolley wires for traction purposes. The locomotives were designed for regenerative working, the substation plant being arranged so that the regenerated energy could be returned to the alternating-current system. Though the conversion was highly successful, after it had been in operation for some time it became clear that to secure the maximum economy it would be necessary to extend electric working southward from Pietermaritzburg to Durban and northward from Glencoe to the Natal border at Volksrust. It was found that this could be done without extending the power station, and that the cost could be reduced by fabricating the track structures locally from scrap rails, by using only a single 88-kV line, and by employing mercury-arc rectifiers instead of motor-generators in the substations.

While, however, rectifiers were cheaper and more efficient than motor-generators, they made it more difficult to deal with the large amounts of regenerated energy which the traffic conditions and gradients rendered available. Nevertheless, after careful investigation, the Electricity Supply Commission decided to equip the new stations with grid-controlled rectifiers, and a contract for twenty such equipments, together with the associated apparatus, was let to Messrs. The British Thomson-Houston Company, Limited, Rugby, to whom we are indebted for the information set out below. These equipments have now been in successful use for over two years; and as they constitute the first large application of inverted rectifiers to main-line electrification some details of their design will be of interest. Moreover, some of the local conditions were sufficiently unusual to make this test of inverted equipment particularly severe.

As a rectifying device can only carry current in one direction, to employ a grid-controlled rectifier for returning direct-current energy to an alternating-current system, the direct-current voltage at its terminals and not the direction of current flow must be reversed. For reversible operation, therefore, it is necessary either to employ direct-current reversing switches or to use a separate tank with a separate transformer secondary winding as an inverter. The former of these is the cheaper and is satisfactory in a few special cases. The total disconnection of the substation, which occurs while the reversing switches are being operated, is, however, an undesirable feature in railway service with heavy trains, as it is liable to give rise to broken couplings and render control difficult. The latter arrangement gives completely smooth and instantaneous reversal, but is costly. A compromise is to use a normal forward-operating rectifier equipment in parallel with an equipment with reversing switches. The second equipment is normally connected as an inverter, but is thrown over to act as a rectifier during times of heavy forward overload. The cost is, however, not much lower than that of two separate equipments. The Electricity Supply Commission solved this problem by using the spare rectifier, which is necessary for the security of forward working, for inverted working as well. Each substation, with a few exceptions, therefore, comprises a rectifier and inverter equipment in parallel. By means of off-load change-over switches, the functions of the tanks can be interchanged or one can be shut down altogether. A diagram of the arrangement is shown in Fig. 1, page 306, in which *a* is the 88-kV oil circuit-breaker, *b* the main transformer with its auxiliary winding *c*; and *d* and *e* the rectifier and inverter windings, respectively. The interphase transformer is shown at *f*, while the rectifier and inverter are shown at *g* and *h*, respectively, with the change-over switches for the latter at *i*. Direct-current reactors are indicated at *k*, and the high-speed circuit breakers at *l*. Resonant shunts are shown at *m*, compounding coils at *n*, and the high-speed feeder breakers at *o*.

With this arrangement, if there should be trouble in one tank the other tank can be used to supply current to the trains, the regenerated current then being handled by the inverters in the adjacent substation. This is possible because the regenerated current is always substantially less than the forward current. As both tanks are equipped with full grid-control apparatus, it was easy to arrange for the latter to give a flat compound characteristic. It was, therefore, specified that the compounding apparatus should maintain the direct-current voltage constant within $\pm 2\frac{1}{2}$ per cent. of 3,000 volts with a constant alternating-current supply voltage between maximum overload in the forward and maximum overload in the inverted direction. It was also specified that the control grids should give arc suppression in the forward operating tank in the event of a backfire. From calculations of the maximum root mean square loads over different periods of the load cycle, the equipments were specified to give a continuous output of 1,667 kW in the forward direction with overloads of 50 per cent. for two hours, 110 per cent. for 30 minutes, 200 per cent. for one minute, and 260 per cent. (6,000 kW) momentarily. In the inverted direction the continuous load was taken as 1,000 kW, with a 25 per cent. overload for two hours, 100 per cent. for 30 minutes, 175 per cent. for one minute, and 200 per cent. (3,000 kW) momentarily. In addition, the sets were made suitable for operation in a tropical climate of high humidity in ambient temperatures up to 40 deg. C. at any altitude between sea level and 5,500 ft., under conditions where dust and insects were prevalent, and in one of the worst lightning areas in the world.

Generally speaking, the rectifiers themselves are of normal design. Attention will, therefore, be confined to the novel features necessitated by the special conditions of the contract. Their appearance is shown in Fig. 13, on page 310. They are of the six-anode type with double control grids and, as will be gathered from the figures previously given, the anode ratings are large. In fact, it is believed that even to-day the forward ratings still exceed those of any other wide-range grid-controlled rectifiers by a considerable margin, while in the inverted direction they are more than double those of any other inverter. The combination of the large rating per anode with the grid-control conditions necessary for the tank to serve either as a rectifier or an inverter made it difficult to find the best form of anode and grid. This will be appreciated when it is pointed out that the grids have to hold back an anode voltage of about 8,500, and they must also give complete certainty of firing. The double control grids, one above the other, are, therefore, excited through separate resistances from the same source of grid voltage. This virtual division of the control grid into two halves permits a grid combination to be used which, it is claimed, gives strong control, while a sort of step-by-step action is able to occur in the firing of the anode. This makes the firing very definite in spite of the "stiff" design of the grids. The use of three-phase excitation also helps to obtain the definite firing that is required.

Other features which may be noticed include the use of damping condensers on the grid circuits to suppress stray transient voltages, the thermostatic control of the anode temperature, the employment of internal cooling tubes accessible from the outside, and an automatic mercury-levelling arrangement. The last prevents the mercury distilling over into or out of the mercury pump as might otherwise readily occur with a closed-circuit mercury pump cooling system in this high ambient temperature. Each rectifier is complete with its own closed circuit recoolers for the main and mercury pump, water-circulating systems, alternating ignition and excitation equipment, and vacuum pumps and gauges. These are all of normal design.

The grids are excited through resistances by a peaked-current alternating-current voltage which is generated in a special peaking transformer. This is superimposed on a constant negative bias voltage, which is furnished by a direct-current generator. This generator is driven by the vacuum-pump motor and is mounted on the rectifier. The principle of operation of the peaking transformer, which is shown at *a* in Fig. 2, page 306, is that the peaked secondary voltage is obtained owing to the small core *b*, which carries the secondary winding *c*, being of insufficient section to carry all the flux required by the applied primary voltage. In this diagram *d* is the rectifier, *e* the anodes, and *f* the grids. The grid resistance and the grid bias generator are shown at *g* and *h*, respectively. As will be seen from Fig. 3, the secondary peak occurs nearly at the point where the flux passes through zero. Consequently, the effect is almost independent of any reasonable variation in the magnetic properties of the core. There is therefore no difficulty in obtaining permanence of characteristics and uniformity between one peaking transformer and another. It is understood that the choice of this type of apparatus, in preference to the synchronous commutator method of exciting the grids, was governed by two main considerations. First, it made the firing more certain, since the peaking transformer can be designed for any desired voltage and current output and there are no limitations, such as those due to sparking, which might make it difficult to apply as much control power as is required to the grids.

The second consideration was associated with the possibility of hunting and load swinging. When it is considered that a phase shift of 3 deg. in the grid voltage of the inverter may be enough to change its load from no load to full load, and that the set works at the end of a transmission line 186 miles long, in which changes of load produce changes in the phase of the high-tension voltage, it is evident that a static form of grid-control apparatus, giving instant response to phase swinging, is most desirable. If there were a delay in the response of the grid-control apparatus to a shift of alternating-current voltage, this might result in a large change of load current which, in turn, might produce a further shift of alternating-current supply voltage, so that under some conditions, hunting could build up. The peaking transformer method of exciting the grids, it is claimed, has the advantage that it does not itself contain anything which can hunt. In addition, owing to its instantaneous response, it not only prevents the main load current of the rectifier or inverter from co-operating in building up hunting, but causes it to have a damping effect, thus reducing the tendency of the system as a whole to hunt from other causes. The peaking transformer also gives the necessary insulation between the grid and low-tension supply circuits. With oil-immersed construction, it has been easy to provide insulation having a large margin of safety. For the same reason, the various resistances in the grid circuits are mounted on panels at the top of the peaking transformers, with effective insulation between the circuits and the earth. The high-speed relay for arc suppression is also mounted on these panels, a view of which appears in Fig. 8, Plate XXII.

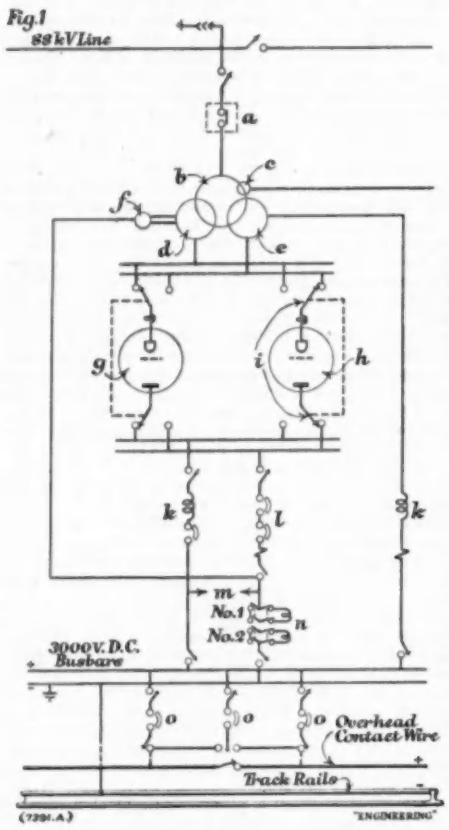
In order to obtain a flat compound characteristic in both directions, the grid voltage must be shifted with the changes of load. The power factor of the railway load as a whole depends, however, on the power factor obtained at medium and heavy loads when rectifying. To keep this power factor reasonably high necessitates the maintenance of a fairly close approximation to the theoretical characteristic. With this characteristic, the rate of shift becomes greater as the forward load is increased. Simple electrical methods of phase shifting, which are, at first sight, attractive, mostly give the reverse of this characteristic, that is the rate of phase shift becomes slower as the load is increased. The result is a hump form of regulation characteristic, which prevents compounding up to such high values of overload, if the direct-current voltage is to be held within the specified limits of $\pm 2\frac{1}{2}$ per cent.

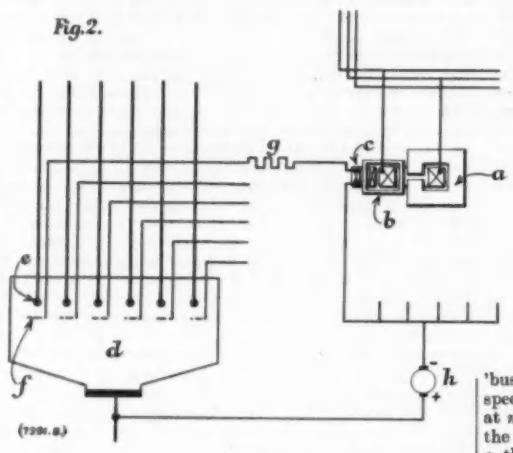
For these reasons, a purely mechanical method of phase shifting was adopted. The apparatus, which is illustrated in Fig. 11, on page 310, consists of an induction regulator type of phase shifter in the primary supply to the peaking transformer. This is rotated, as a function of the load, by a direct-current torque motor, which acts against a spring. The torque motor, the design of which is similar to that of those used for synchronous-motor field control in the earlier motor-generator substations, has its armature supplied from a constant-voltage source of direct current, while its main field winding carries the main load current. There is also a dash-pot at the bottom, which gives approximately critical damping. With this arrangement, a curved characteristic is produced when rectifying by causing the displacement of the phase shifter to cut out a resistance in the torque-motor armature circuit as the phase shifter is advanced by means of the rheostat seen at the left of Fig. 11. When the connections are changed over from rectifying to inverting, this continuously-varying rheostat is replaced by an adjustable fixed rheostat so as to give the changed and substantially constant rate of movement with the load that is then required. At the same time, the armature current is reversed so that the direction of movement with the load is still correct.

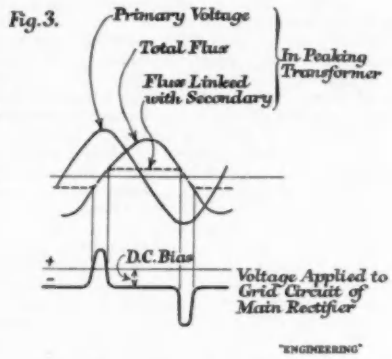
The torque-motor arm engages with a stop to prevent retardation being carried too far when inverting and also to prevent advancement being carried too far at extreme overloads when rectifying. The change of phase of grid voltage relative to anode voltage, as between rectifying and inverting, is given partly by appropriate connections in the main anode change-over switchgear, partly by changing the terminals to which connection is made on the phase-shifter stator and partly by the initial phase shift when rectifying which is produced by an additional, shunt-excited, field winding on the torque motor. This shunt field winding is excited only when connected for rectifying. By varying the current in it by the rheostat, the direct-current voltage can be raised or lowered in a similar way to that of a direct-current generator. The circulating current between the rectifier and inverter can also be similarly controlled. The torque motor and phase shifter are at low voltage and any desired adjustment can, therefore, be made while the plant is alive.

The question of stability of parallel operation of the compound rectifier and inverter also required consideration. If the compound apparatus is simply connected in series with the cathodes of the individual tanks, the conditions are, or can easily become, unstable, *i.e.*, an increase of circulating current due to any cause will raise the voltage of the rectifier and depress that of the inverter, thus tending to produce a further increase of

REGENERATIVE WORKING ON THE SOUTH AFRICAN RAILWAYS.







circulating current. In fact, with such a connection, stability can only be obtained by working very nearly in shunt. The difficulty was overcome on these South African equipments by arranging the connections so that the circulating current did not pass through the compounding apparatus, but only the total output current of the substation. This connection, which is shown in Fig. 1, is equivalent to the equaliser connection commonly used in the parallel operation of compound rotating machines, but, it is claimed, is more effective owing to the load current passing through the compounding equipments in series. With this arrangement, perfect stability of circulating current is, of course, obtainable with level compounding in both directions or even with over-compounding. As the total output current of the station passes through both torque motors, by-pass isolating switches of the make-before-break type are provided in the main series connections to the torque motors. Any motor can, therefore, be taken completely out of service if required without interrupting the supply from the substation.

The effect of passing current through the torque motor in the opposite sense to that required for compounding is of interest. An increase in the forward current supplied by the substation causes the rectifier torque motor to advance the phase of its grid voltages (as is required for compounding) and at the same time causes the inverter torque motor to move in the opposite direction. This raises the direct-current voltage of the inverter slightly, thus keeping the circulating current small. Excessive retardation of the inverter grid voltage, which would lead to short-circuit, is, however, prevented by the torque-motor arm engaging with the stop, as shown in Fig. 11. In the case of an increase of regenerated current fed to the substation, the inverter grid voltages are advanced as required for compounding and the rectifier grid voltages are retarded. In this case, however, the rectifier torque motor goes on retarding past its no-load setting, i.e., to the point where its series and shunt fields neutralise each other, before the stop is reached. This gives a valuable increased margin of stability of the circulating current when regenerated current is flowing. Owing to these features and to the value of the damping provided, the circulating current is maintained correct both during rapid changes of load and steady-state conditions.

The disadvantages of taking a separate small supply from a large high-voltage system, especially in a district where lightning is prevalent, are well known. Consequently, it was decided to supply the rectifier auxiliaries and various other loads in and near the substation from an auxiliary winding on the main transformer. This was permissible owing to existence of the anode change-over switches, as these enable the rectifier or inverter to be disconnected without shutting down the main transformer. The design of the main transformers, which are illustrated in Fig. 7, Plate XXII, was thus unusually interesting. Not only had four separate windings to be provided, but the location of these windings with respect to one another in the transformer had to be carefully studied in order to obtain suitable values of reactance between each winding and the others. The primary winding had to be specially insulated for the severe lightning conditions and the complete transformer had to pass a rather small loading gauge.

From what has been said above it will be realised that a fairly low voltage inverter winding is necessary in order to obtain the maximum power factor on inverted loads, whereas for maximum reliability of inversion this voltage should be high relative to the direct-current voltage. In the case of the South African equipment, the power factor of the inverted load was unimportant since although large inverted loads are met with at the individual substations, the total inverted load on the system at any given time is negligible compared with the forward loads. On the other hand, the great length of the alternating-current transmission line and the heavy inverted peak loads make it necessary to do everything possible to make the inverter as stable and reliable as possible. The voltage of the inverter winding was, therefore, made high, being 3,700 volts from anode to neutral. This corresponds to a rating of 3,000 kVA, the connection being six-phase triple star. The rectifier winding is connected six-phase double-star with a voltage to neutral of 2,930 volts, and a rating of 2,820 kVA. The interphase transformer for this is mounted in a separate tank, as shown in Fig. 7, Plate XXII. The auxiliary winding on the main transformer is rated at 100 kVA, 380/220 volts, with the neutral brought out. The primary winding, allowing for the combined loads on the other windings, is rated at 2,500 kVA, and is star-connected for 88 kV, 50 cycles, with full-capacity off-load tappings of +3 per cent., 0, −3 per cent., −6 per cent., and −9 per cent.

The governing consideration in the design of the auxiliary circuits was to reduce the number of points where breakdown could take place from apparatus at 3,000 volts direct-current potential to earth as much as possible, since many of the auxiliaries of the tank acting as rectifier must operate at this potential. With this object, all small insulating transformers between these high-voltage circuits and earth-potential circuits were eliminated, leaving only three insulating transformers, namely, the peaking transformer for the grids, the ignition and excitation transformer, and one main insulating transformer. These three transformers are large enough to have ample insulation and are of oil-immersed construction. The connections are shown in Fig. 4, opposite, in which *a* is the 88-kV line, *b* the oil circuit-breaker, *c* the main transformer with its interphase transformers, auxiliary winding and surge arresters, *d* the 380-volt auxiliary 'bus bars from which the lighting, battery-charging sets, control gear and take-out transformer are supplied, and *e* the anode change-over switches which enable the tank to be used either as a rectifier or an inverter. These switches, like those for the cathodes at *f*, are interlocked with control change-over switches to ensure that they all are in corresponding throw. The two rectifiers are shown at *g*, and the rectifier and inverter high-speed breakers at *h* and *i*, respectively. The 3,000-volt direct-current 'bus bars are indicated at *k*, the direct-current high-speed breakers at *l*, and the overhead contact wire at *m*. The auxiliaries of No. 2 converter are shown on the right of the diagram, *n* being the phase shifter, *o* the peaking transformer, and *p* the ignition and excitation transformer and controls. The grid-bias generator is indicated at *q*, the insulating transformer at *r*, and the main recooler blower motor at *s*. The mercury pump, mercury-pump recooler, electrical vacuum gauge, and the rotary vacuum and water-circulating pumps are among the auxiliaries conventionally indicated at *t*, while the torque motor and its adjusting rheostats are shown at *u*. All the 3,000-volt auxiliary circuits are segregated by mounting them on separate panels on porcelain insulators, and the control interlocks between the high-tension and low-tension circuits are provided by insulating links. These high-tension control panels are sub-divided into four sections in each tank:—One for the grid-control circuits and arc suppression, as shown in Fig. 8, Plate XXII, one for the ignition and excitation, which is illustrated in Fig. 10, Plate XXII, one for the Pirani gauge, and one for the general high-tension control gear.

All the high-tension auxiliaries associated with each tank are located adjacent to that tank in a locked enclosure. As a further precaution against breakdown to earth, the high-tension auxiliary wiring between the various high-voltage auxiliary panels and from them to the rectifier, is carried directly across in conduit pipes, so that its insulation is not subject to the potential difference to earth. The grid control, ignition and excitation and general auxiliary circuits are kept separate from one another.

The general control scheme is that the stations are unattended, the plant being equipped with all the necessary protective features and alarms being sounded in the neighbouring attendant's quarters in the event of a shut-down. Starting up, reclosure of circuit breakers, and interchanging the function of the two tanks are done manually. The anode and cathode change-over switches, which are shown on the left of Fig. 9, Plate XXII, and are used for interchanging the function of the tanks, are gang-operated and interlocked so that two tanks cannot be paralleled on the same transformer winding. The corresponding change-over of the control circuits, all of which are at low tension, is effected by the drum controller visible in the centre of the common low-tension control panel, illustrated in Fig. 12, page 310. Castell key interlocks ensure that the control change-over switch must be in the same "throw" as the anode and cathode change-over switches before starting up is possible. A main substation battery is provided for operating the various circuit-breakers and for general control purposes. There are also two small motor-generator sets which are connected to the 380-volt alternating-current supply. These are available for battery charging and for giving the constant-voltage direct-current supply for the armatures and shunt fields of the torque motors. A portable bake-out transformer is also provided and can be used to bake out any tank on the system. It is supplied from the 380-volt auxiliary circuits. The bake-out current is controlled by a small portable loading resistance at the lower values and by a grid at higher values. For this purpose, the hand-wheel shown at the top of the phase shifter in Fig. 11, on page 310, is used. The anode and cathode change-over switches and the associated control gear permit either tank to be baked out in safety while the other tank is on load.

The general arrangement of the direct-current switchgear can be seen in Fig. 5, Plate XXI. The 3,000-volt high-speed circuit-breakers are mounted in cubicles on a gallery with the direct-current 'bus bars and isolators beneath them. The isolators are remote electrically operated, and Castell key interlocks prevent a high-speed breaker compartment being isolated until the breaker itself has been isolated on both sides. There

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(*For Description, see Page* 305).

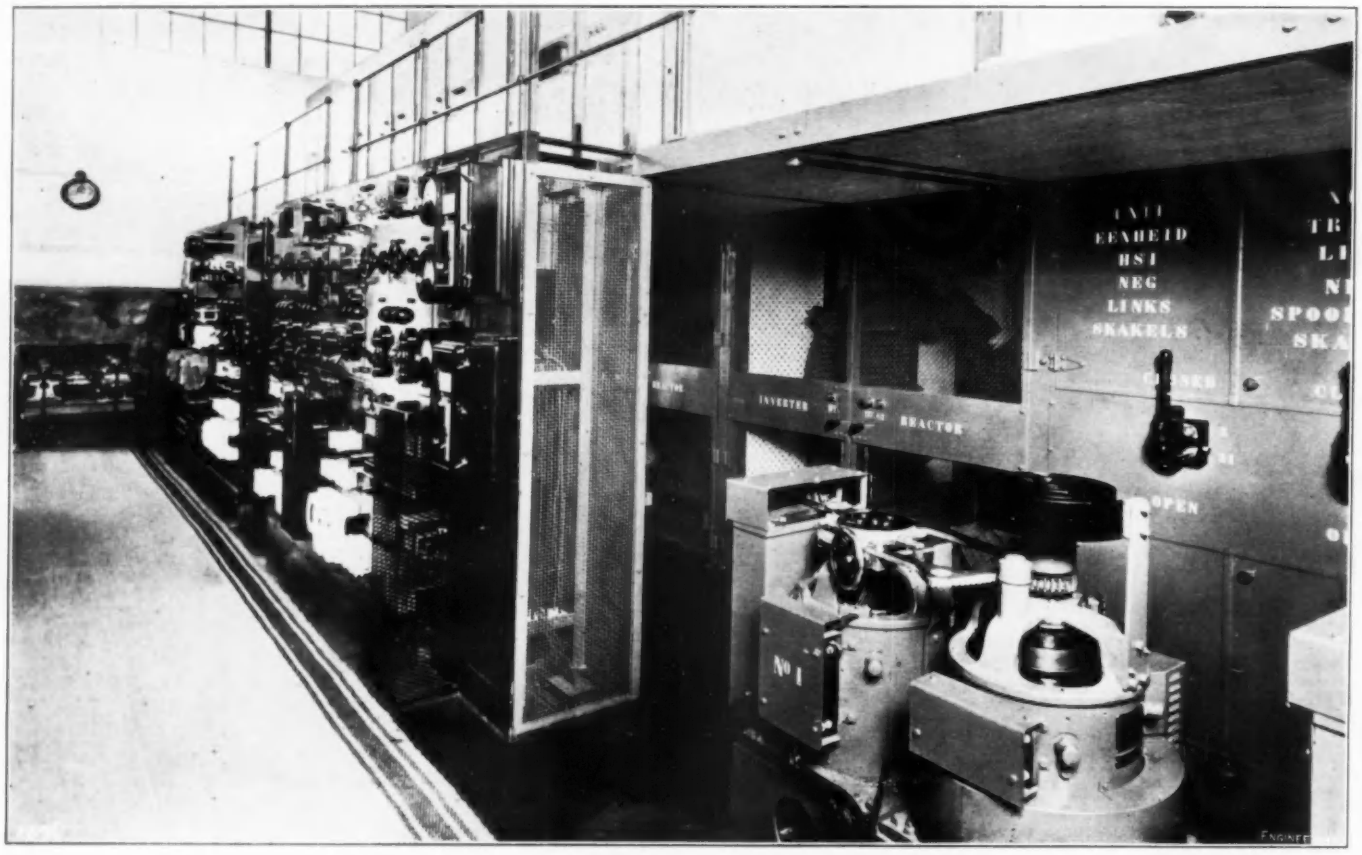

Fig. 5. 3-KV. Direct-Current Switchgear and Low-Tension Control Gear.

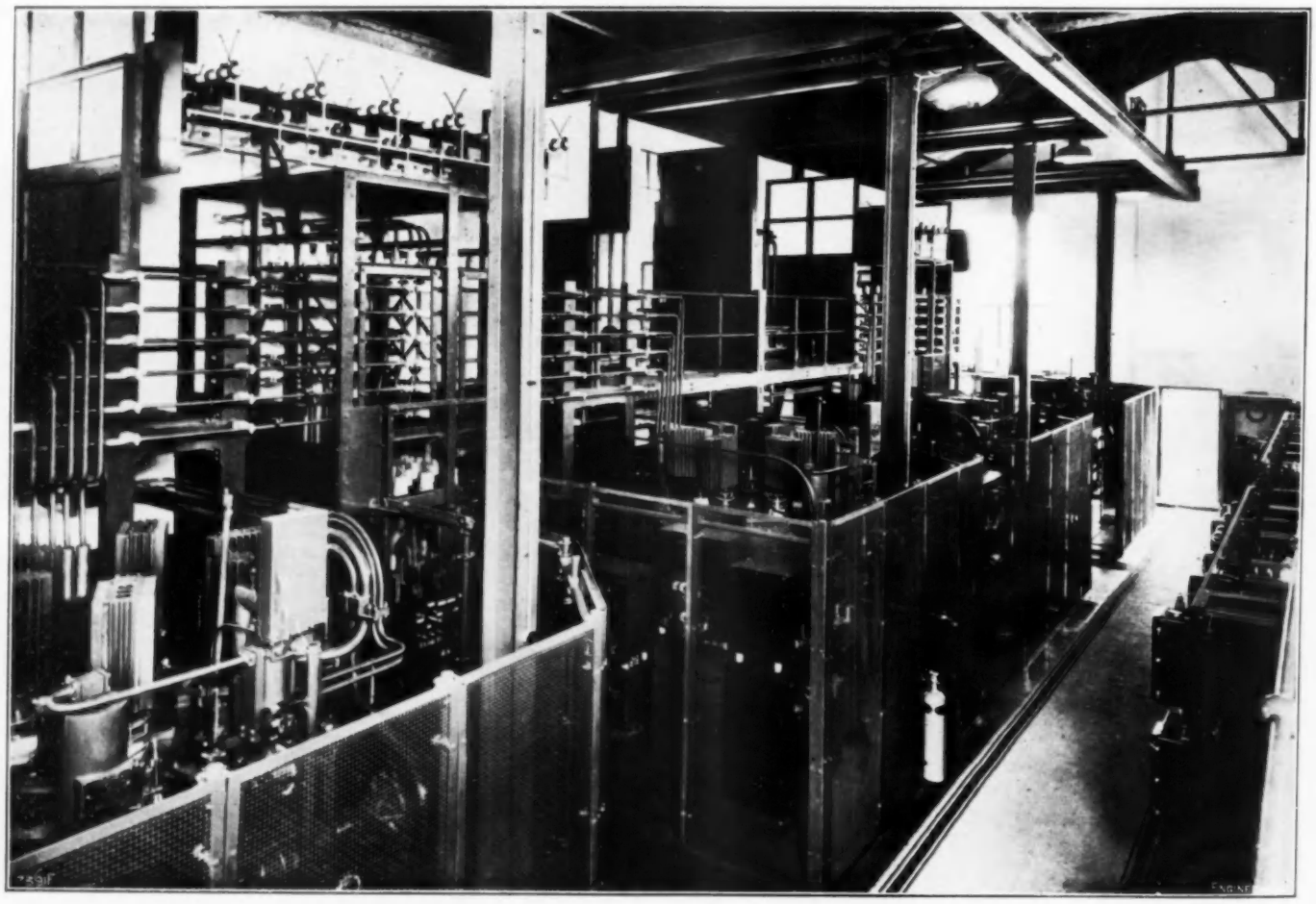

Fig. 6. Interior of Booth Substation showing Rectifiers.

(*To face page* 306.)

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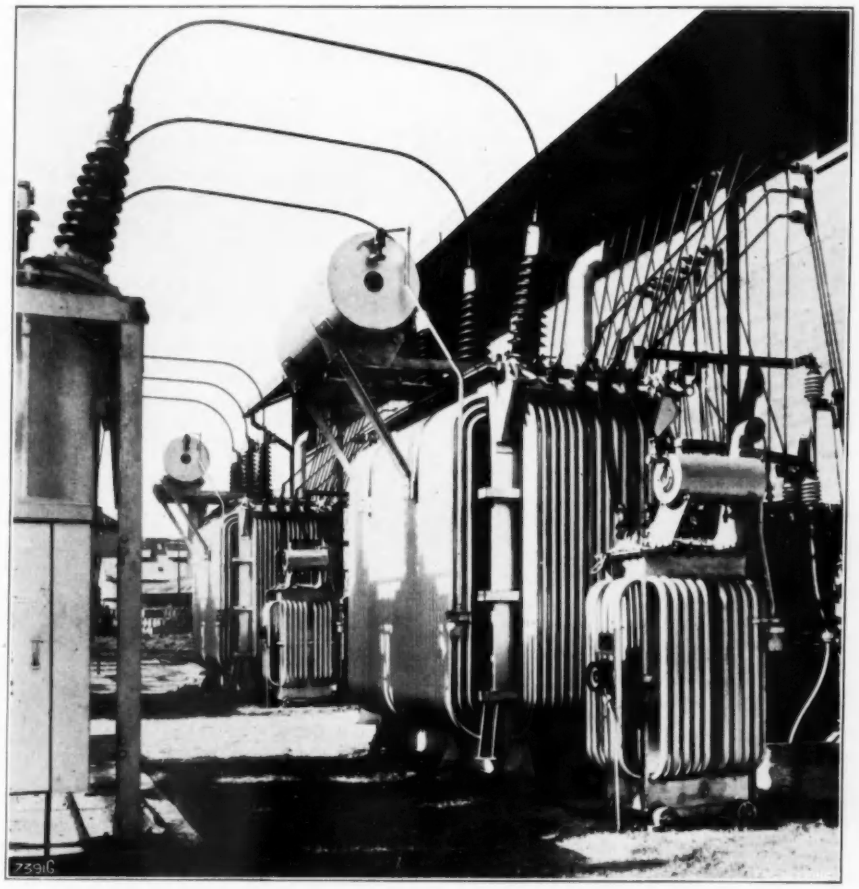

Fig. 7. Main and Interphase Transformers.

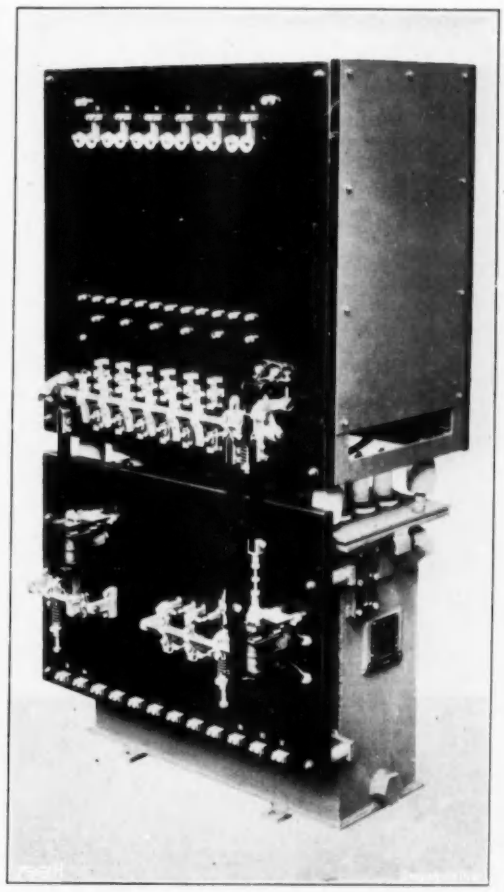

Fig. 8. Peaking Transformer.

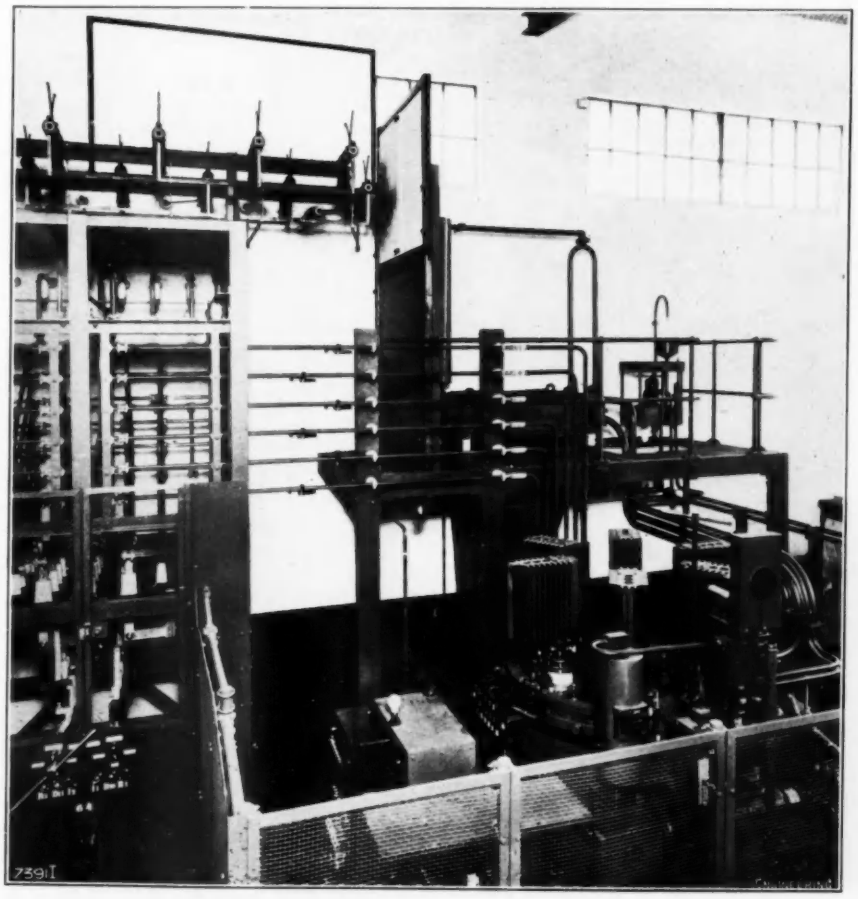

Fig. 9. Anode and Cathode Change-over Switch Cubicle.

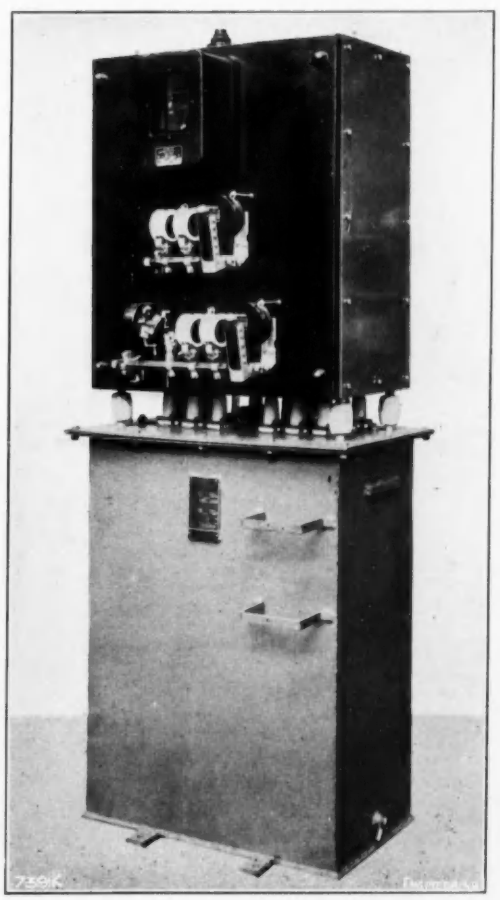

Fig. 10. Ignition and Excitation Transformer and Control Panel.

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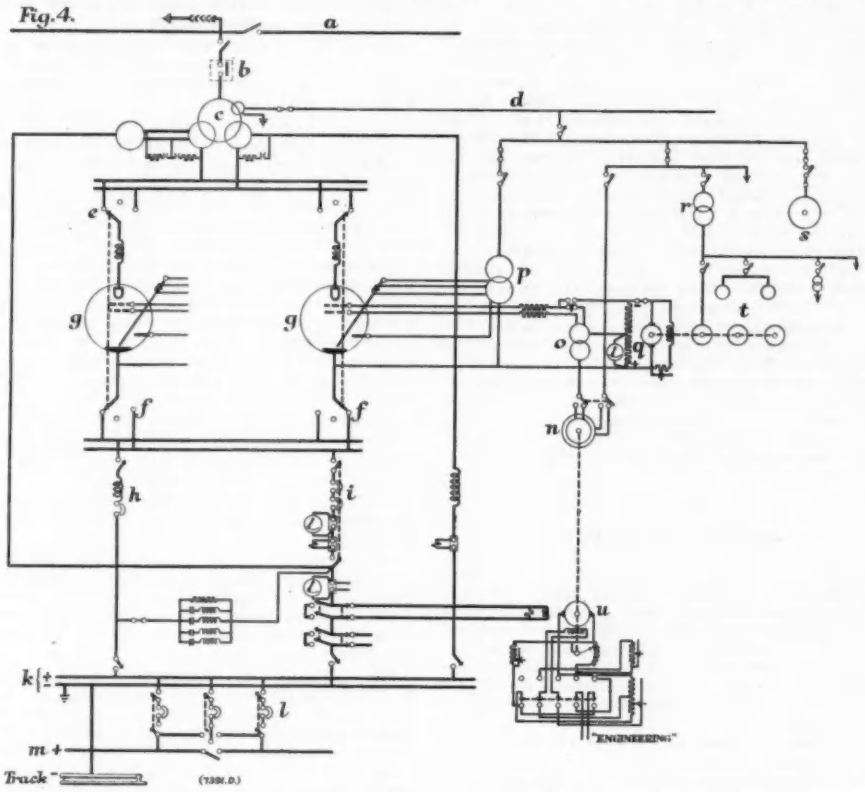
REGENERATIVE TRACTION IN SOUTH AFRICA.

Fig. 4.



are also Castell key interlocks to prevent any isolator or change-over switch being opened on load. A similar system of key interlocks ensures that the rectifier enclosure cannot be entered until it has been made completely dead.

The standard substation arrangement just described is modified in three cases. At Dannhauser and Newcastle, the anticipated inverted loads were small enough to be dealt with in the adjacent substations and no inverters were, therefore, installed. These two stations are also arranged for fully automatic control. At Booth, near the Durban end of the line, a view of which is given in Fig. 6, Plate XXI, the anticipated forward loads were too great for a single rectifier and it has, therefore, been arranged as a double-unit regenerative substation; that is, it contains two sets, each consisting of a rectifier, inverter, common transformer and associated apparatus. Only one inverter, however, is used. This arrangement created a special problem in regard to the compounding apparatus, since it was desirable to adhere to the connection of the torque-motor main field in series with the total output of the station. With such a connection, however, the series field windings would not be suitable for carrying the combined currents of two rectifiers; neither would they give the correct compound characteristic if they did so. It was also necessary that the equipment should work correctly if only one rectifier were in service instead of two. The torque motors, therefore, remain in series with the total output of the station, but are shunted by a resistance equal to the combined resistance of three torque motors plus their connections. The contactor in the diverter circuit opens under the control of the reverse-power relay when inverted current is flowing and it is also opened if only one rectifier is working. Consequently, the flat compound characteristic in both directions is correctly given irrespective of the number of rectifiers in service and the circulating current is still comparatively stable. A failure of the diverter contactor would merely result in the characteristic being partially shunt instead of flat compound.

During tests in the makers' works on a complete substation equipment, the generated loads and overloads were carried and repeated rapid load swings from 4,500 kW forward to 2,000 kW inverted were successfully effected. The overall efficiency at full load was 96 per cent. when rectifying and 94 per cent. when inverting. The total loss under the same conditions was 25 kW. The full-load power factor exceeded 0·91 when rectifying and 0·58 when inverting. As regards performance in service, tests were made at the outset, consisting of the simultaneous operation of two 1,000-ton trains on a gradient of 1 in 70, both upwards and downwards, with a single rectifier and inverter to supply them. The corresponding apparatus was also tested. These tests were found to be completely satisfactory and the parallel operation of the flat compound rectifier and inverter was completely stable. Remarkable loads have been carried at times. Operating as a rectifier, a single tank has successfully carried nearly three times full load for over 10 minutes, while inverted loads of over 3,000 kW have been carried without difficulty on a single unit.

The method of exciting the grids by static apparatus has proved its value, as both rectifier and inverter have been found to operate steadily without sudden swings of current or hunting. Actually the equipments have been tried experimentally on an already hunting alternating-current system and found to work steadily. The speed of response of the torque motors to variations of substation load has proved to be ample. The automatic levelling arrangement on the mercury pumps has also been very successful. With cooling-air temperatures up to the maximum of 40 deg. C. normally permitted for these equipments, no mercury pump has had to have its mercury level attended to in over three years' service. Perhaps the most important point that had to be determined by service experience was the degree of reliability obtainable with inverter equipments at the end of a long transmission line with large overloads and large voltage surges. Experience has shown that these conditions affect the inverters less than might have been expected. Actually, the interruptions on the inverters have been very few and not greater than on the rectifiers. The severe lightning conditions in the district have proved the principal source of interruptions. As regards lightning surges coming in from the direct-current side, flash-over, with resultant damage, has occurred in a few instances on the outgoing direct-current feeder equipments. Short lengths of cable from 40 yards to 12 yards long have, therefore, been inserted in the direct-current feeders in most substations to reduce the severity of the lightning stresses on the equipments. With this exception, there have not been any actual plant breakdowns due to lightning, and the thorough insulation to earth of the main and auxiliary 3,000-volt circuits has thus proved its value.

As regards the alternating-current side, lightning surges from the 88-kV lines pass through the transformers and appear on the secondary windings across the anodes of the rectifiers and inverters. That the high voltages on the secondary windings are due to this cause has been demonstrated by operating the transformers with the rectifiers and inverters disconnected. Voltages of between 20 kV and 30 kV thus become impressed on the anodes and, although the insulation is sufficient and no breakdowns have occurred, the condition is nevertheless severe and has resulted in occasional interruptions on the rectifiers and inverters. The tanks have shown themselves to be somewhat more sensitive to these surge voltages when acting as rectifiers than when acting as inverters. A study has been made of the methods by which these over voltages on the anodes can be reduced, but it has not so far been considered necessary to modify the equipments for this purpose, as the interruptions are less frequent than those caused by ordinary track faults.

A complication encountered has been resonance on the 88-kV transmission lines. The length of line between Colenso and Booth is 186 miles, which makes it exactly a $\frac{1}{4}$ wavelength line for the fifth harmonic. In consequence, strong resonance with the fifth harmonic builds up under suitable load conditions. In the opposite direction, the distance from Colenso to Volksrust is not much less, and resonance again occurs under suitable load conditions. The case is a particularly difficult one, because the load on this system is almost exclusively for traction purposes; that is, the damping effect of the general load on the alternating-current system goes down at times to a very low value. This resonance affects the operation of the substation equipments in two ways. In the first place, it produces a very slight shift of the grid voltage which tends to reduce the circulating current between rectifier and inverter to a point where (due to the finite value of the smoothing inductance) the circulating current becomes discontinuous. Secondly, the resonance produces large over-voltages on the transformer secondary windings and anodes which, at times, reach very high values and are of importance because they may persist for considerable periods. These over-voltages have been proved to contribute to the occasional interruptions previously mentioned. They also constitute a further difficult condition for the anode surge arresters. On about five or six occasions the over-voltages due to resonance have persisted so long that the resultant sustained arcing at the horns of the surge arresters has only been interrupted by shutting down the equipments, either manually or by operation of the protective devices. It may be mentioned that sustained voltages above normal, but below the spark-over value of the horn gap, are cleared by the arresters without difficulty and the occasions when they have suffered damage have been few. The fireproof construction of the arresters, it is claimed, has contributed to this result. It is worth noticing that the peaking transformers have proved so insensitive to these large distortions of alternating voltage wave form that the only effect produced is a slight alteration of the circulating current. It has also been necessary to make a number of minor alterations in the automatic control gear to prevent interruptions which had previously occurred due to control contacts dropping out as the result of momentary dips in the alternating voltage. The contactors in question were of normal construction and drop-out voltage, and it is noteworthy that the inverters have actually been found less sensitive to such fluctuations of alternating voltage than the contactors themselves.

In the forward direction, the load factors reach figures which are very high for main-line service. In 1939, for instance, the annual figure was 64·2 per cent. at Booth and reached 40·6 per cent. at Delville Wood. These load factors are averages over long periods, including nights and week-ends, and do not include the internal circulating current between rectifier and inverter in the same substation. In fact, the load factor for Booth substation, which averaged 73·5 per cent. in November, is one seldom obtained in railway practice. In considering how far the provision of inverters is justified by the loads carried, it must be remembered that, in any railway system with regenerative braking, the energy returned to the line at the substation is never more than a percentage of the energy regenerated at the trains, since much of the latter is absorbed in nearby motoring trains. The value of this percentage at the substations naturally varies according to the contour and traffic conditions on the line; and it may be said that upon it depends the question of whether it is better in any given case to employ inverters or to dissipate the surplus regenerated energy at the substations in resistances. Generally speaking, when the traffic is heavy, the percentage regenerated energy at the substations is low, both because the forward energy figure is higher and because there is generally a better chance of the energy returned by a regenerating train being absorbed by a motoring train in the neighbourhood. Excluding the special case of the Booth substation, the energy regenerated during 1939 was 12·39 per cent. of the forward energy. In spite of the exceptionally heavy traffic, 20,000 tons to 30,000 tons a day in each direction, the choice of inverters may, therefore, be said to have been correct.

RUSSO-FINNISH RAILWAY SERVICE.—Railway connection between Leningrad and Helsinki has now been re-established.

BRITISH STANDARD SPECIFICATIONS.

The following specifications of engineering interest have been issued by the British Standards Institution. Copies are obtainable from the Publications Department of the Institution, 28, Victoria-street, London, S.W.1, and, unless otherwise stated, the price is 2*s.* net, or 2*s.* 3*d.* including postage.

High-Alumina Cement.—As it was considered desirable for a specification for high-alumina cement to form the subject of a separate publication and not to embody it in the revised specification for Portland cement (No. 12-1940), a new one, designated No. 915-1940, has been prepared and issued. The general form of the specification, however, follows lines similar to those of the specification for Portland cement. As in the case of high-alumina cement, however, there is no traditional tensile test, the compression test has been included without the alternative of a tensile test.

Bolted Flame-Proof Cable Couplers.—A new specification for electrical apparatus primarily for use in mines is No. 912, which deals with bolted flame-proof cable couplers, which are also capable of being used as detachable dividing boxes. They are so designed as to enable two or more cables, of various descriptions, to be coupled together or to enable a cable to be coupled to apparatus. The publication relates to two types of couplers for any voltage up to 3,300 volts, namely, the link type and the contact-pin and contact-tube type. In either type it is intended that the two or more units which comprise a coupler shall be attached to one another by bolts, studs, or screws, and so constructed as to permit subsequent detachment of the units without disturbing the attachment of the cable thereto. The specification covers mechanical strength, flame-proof enclosure, and self-alignment, and the materials and construction of the case, the insulation, the contact pins, and the links. Particulars of high-voltage tests and tables of electrical clearances and standard voltage and current ratings are also included.

Fluorescent and Phosphorescent Paints for A.R.P. Purposes.—The Institution has recently published a revision of B.S./A.R.P. No. 18, which deals with fluorescent and phosphorescent paints for air-raid precautions purposes. The specification was originally published in December, 1939, and the main points of difference between the new and the earlier edition are the extension of the specification to cover paints other than those giving a greenish light and the inclusion of a simpler form of brightness test as an alternative to the visual brightness photometer method. The latter has proved difficult for laboratories not specially equipped for the work of measuring brightness of the order of 0·001 equivalent foot-candle. A unit referred to as "effective brightness" has been adopted to take the place of the more usual unit of equivalent foot-candle. It is pointed out that, owing to the fact that, at low brightness, the eye becomes progressively more and more blue-sensitive, the judging of the merits of differently-coloured luminescent paints, on the basis of their equivalent foot-candles, does not give a true measure of their relative practical usefulness. The basis adopted in the specification is the visual comparision of any surface with a white diffusing surface illuminated by light from a tungsten-filament lamp, operating at a colour temperature of 2,300 deg. K., the brightness of the white surface in equivalent foot-candles being defined as the product of its reflection-factor ρ and its illumination in foot-candles. This illumination is found by dividing the candle-power of the lamp I by the square of the distance of the lamp from the surface in feet d. The brightness of the white surface is, therefore, $\frac{I}{\rho d^2}$ equivalent foot-candles, and any coloured surface, judged by a normal observer to be equally bright, is said, for the purpose of the specification to have an "effective brightness" of 1,000 $\left(\rho \frac{I}{d^2}\right)$ units, provided that the areas of the surfaces compared subtend an angle of at least 5 deg. at the observer's eye. It will be seen that the unit of effective brightness, thus defined, is equal to 0·001 equivalent foot-candles, for light having a colour temperature of 2,300 deg. K. The unit of effective brightness is also equal to 0·001 foot-lambert; 0·001076 millilambert; or 0·000318 candles per square foot. [Price 1*s.* 3*d.*, postage included.]

Railway Services in Holland.—The services on the Netherlands Railways have been severely curtailed by the German forces in occupation of the country. It is stated in *Modern Transport* that, in areas in which a ten-minute service was the rule before May 10, few trains are now running, while in less densely populated districts there are no trains at all. A large proportion of the rolling stock has been sent to Germany.

REQUISITIONED COPPER.

Under the Defence (General) Regulations, 1939, the Minister of Supply has requisitioned further tonnages of copper lying in warehouses owned by Messrs. Henry Bath and Son, Limited, Liverpool; Messrs. Fellows, Morton and Clayton, Limited, Birmingham; the Tyne Improvement Commission, Newcastle-upon-Tyne; and Messrs. Thos. Cheshire and Company, Limited, and Messrs. Henry Diaper and Company, Liverpool. Copper lying at the Colonial, Millwall and Orchard Wharves, London, has also been requisitioned. Owners of copper lying at these places should inquire whether their metal has been requisitioned. The present step follows on the requisition made in July, when copper lying in Messrs. Weber, Smith and Hoare's Metropolitan and New Crane Wharf was taken over. Applications for compensation should be sent to the Controller, Non-Ferrous Metals Control, Grand Hotel, Rugby. Invoices and warrants should be sent with the application. The prices of requisition are: for rough copper, 54*l.* per ton, London Metal Exchange standard copper contract terms; for fire-refined copper, 57*l.* 10*s.* net per ton; and for electrolytic copper, 59*l.* per ton in the case of wire bars or ingot bars and 58*l.* 10*s.* per ton in that of cathodes. Rent should be deducted on the invoice up to and including September 23, 1940.

BOOKS RECEIVED.

United States National Bureau of Standards. Building Materials and Structures. Report BMS51. *Structural Properties of "Tilecrete Type A" Floor Construction Sponsored by the Tilecrete Co.* By H. L. Whittemore, A. H. Stang and D. E. Parsons. Washington: Superintendent of Documents. [Price 10 cents.]

Methane: Its Production and Utilization. By Dr. J. P. Lawrie. London: Chapman and Hall, Limited. [Price 6*s.* net.]

Textile Testing. Physical, Chemical and Microscopical. By Professor J. H. Skinkle. London: Macmillan and Company, Limited. [Price 15*s.* net.]

Physical Science in Art and Industry. By Dr. E. G. Richardson. St. Hugh's School, Bickley, Kent: English Universities Press, Limited. [Price 15*s.* net.]

British Standards Institution. No. 185/1940. *British Standard Glossary of Aeronautical Terms.* Revised August, 1940. Provisional Edition for War-Time Use. London: Publications Department, British Standards Institution, 28, Victoria-street, Westminster, S.W.1. [Price 7*s.* 6*d.* net.]

Department of Scientific and Industrial Research. Forest Products Research. Bulletin No. 19. *Beetles Injurious to Timber and Furniture.* London: H.M. Stationery Office. [Price 1*s.* 6*d.* net.]

State of Tennessee. Department of Conservation. Division of Geology. Bulletin No. 48. *The Phosphate Resources of Tennessee.* By R. W. Smith and G. I. Whitlatch. Nashville, Tennessee, U.S.A.: State Geologist, Department of Conservation, State of Tennessee.

University of Michigan. Proceedings of the Twenty-Sixth Annual Highway Conference. Held at the University of Michigan. February 15 to 17, 1940. Ann Abor, Michigan, U.S.A.: University of Michigan.

United States War Department. Port Series No. 12. (Revised 1939.) *The Ports of San Francisco, Oakland, Alameda, Richmond and Upper San Francisco Bay, California.* Washington: Superintendent of Documents. [Price 1.75 dols.]

United States National Bureau of Standards. Building Materials and Structures. Report BMS 53. *Structural Properties of a Masonry Wall Construction of "Munlock Dry Wall Brick" Sponsored by the Munlock Engineering Co.* By H. L. Whittemore, A. H. Stang, and D. E. Parsons. Washington: Superintendent of Documents. [Price 10 cents.]

Road Bridge at Weston-super-Mare.—The bridge over the railway at Weston-super-Mare, which has long constituted a source of danger to road traffic, has been rebuilt. The cost of the work was 17,279*l.*, and the Ministry of Transport has contributed 75 per cent. of the outlay.

Institution of Electrical Engineers.—As mentioned elsewhere in this issue, a meeting of the Institution of Electrical Engineers will be held at Savoy-place, Victoria-embankment, London, W.C.2, on Thursday, October 24, when the President (Mr. J. R. Beard) will deliver his inaugural address. An Ordinary Meeting will also be held on Thursday, November 14, at 12.30 p.m., for the sole purpose of complying with the bye-laws relating to the election and transfer of members. Until further notice, the library will be open from 9.30 a.m. to 4.30 p.m.

PERSONAL.

Mr. C. J. Pocock has been promoted from the position of first assistant harbour engineer to that of chief assistant harbour engineer, Ceylon.

Messrs. Modern Machine Tools, Limited, inform us that they have now moved their entire works, showrooms and offices to more commodious premises erected in Maudslay-road, Coventry.

Messrs. Crypton Equipment, Limited, have transferred their works from North Acton-road, Park Royal, London, N.W.10, to St. Mary's-street, Bridgwater, Somerset.

Mr. Rowland Walker, M.I.Chem.E., is to become chief engineer of the Manchester Corporation Gas Department at the end of the present year.

The offices of The Society of Chemical Industry are now housed in the Imperial College of Science, Prince Consort-road, London, S.W.2, to which address all communications regarding the affairs of the Society should be addressed.

Mr. W. A. F. Graham, hitherto assistant to the general manager, Great Northern Railway of Ireland, Dublin, has been made deputy traffic manager of the undertaking, with a headquarters' office in Belfast.

Mr. E. J. Missenden, general manager, Southern Railway, has been elected a director of the East Kent Railway Company, in succession to Lt.-Col. G. S. Szlumper, C.B.E., who has retired from the board on his appointment as Railway Control Officer, Ministry of Transport.

Captain J. W. Jones, of Bristol, has been elected chairman of the National Council of Associated Road Operators for the ensuing year. He was previously acting chairman, having been appointed to that position when Lieut.-Commander J. W. Havers rejoined the Royal Navy a few months ago.

Mr. Vernon L. Farthing, A. M. I. Mech. E., M.I.Mar.E., M.Inst.Pet., consulting engineer, 528, Tower-building, Water-street, Liverpool, 3, has taken up an appointment under the Ministry of Supply as North-Western Area Officer, War Office Inspection Department, with offices in Manchester. His assistant, Mr. Frank Booth, is carrying on the practice and the engineering agency business of Messrs. V. L. Farthing and Company. It may be recalled that we stated in this column on page 288, *ante*, that Mr. Farthing had resigned the position of honorary secretary of the Liverpool Engineering Society. He took this step after accepting his new appointment.

Mr. G. H. Johnson has succeeded his father, Mr. H. S. Johnson, as president of the Gisholt Machine Company, Madison, Wisconsin, U.S.A. Mr. G. H. Johnson represents the third consecutive generation of the Johnson family to hold this position, the company having been founded by his grandfather, Mr. J. A. Johnson, in 1889. Mr. H. S. Johnson is now chairman of the board.

TENDERS.

We have received from the Department of Overseas Trade, Great George-street, London, S.W.1, particulars of the undermentioned tenders, the closing dates of which are stated. Details may be obtained on application to the Department at the above address, quoting the reference number given.

Road-Making Machinery, including motor lorries, mechanical shovel, road rippers, pumps, drilling machines, presses, air compressors, and tractors. Orange Free State Tender Board, Bloemfontein, South Africa; October 30. (T. 21,991/40.)

Steam Turbo-Alternator Set. With reference to the call for tenders for a 50,000-kW steam turbo-alternator set for Bunnerong Power Station, noted on page 48, *ante*, we now learn that the Sydney County Council, Sydney, New South Wales, has extended the closing date from October 24 to January 9, 1941. (T. 16,057/40.)

Transformers, two, 3,000-kVA, 11-kV, three-phase, 50-cycle, outdoor-type, for the Matamata and Edgecombe substations. Public Works Department, Wellington, N.Z.; January 14, 1941. (T. 22,238/40.)

Telephone Equipment, comprising switchboard keys. Posts and Telegraphs Department, Melbourne, Australia; November 5. (T. 22,242/40.)

The Evaporation of Water from Saturated Surfaces: Erratum.—We regret that in our abridgement of Dr. R. W. Powell's paper on the above subject, read before the Institution of Chemical Engineers in March last, an error occurred in formula (4) which appears near the bottom of the left-hand column on page 239, *ante*. The correct form of the formula is:

$$\frac{e\,d}{(p_w - p_a)} = 3{\cdot}3 \times 10^{-7}\,(u\,d)^{0{\cdot}56}.$$

NOTES FROM THE SOUTH-WEST.

CARDIFF, Wednesday.

The Welsh Coal Trade.—Steady conditions ruled for Welsh steam coals throughout the past week. In the home trade, activities were well maintained, and as deliveries of some substantial orders, held by producers in connection with customers' stocking programmes, will continue for some months to come, coals were assured of a very good outlet. Consequently, the collieries were able to maintain operations on recent reduced levels, and it did not seem likely that any further early curtailment in operations would become necessary. The export section did not show any material improvement, and the general volume of trade passing was limited. Moderate business was done with South American buyers, and a steady rate of deliveries was maintained, but there was no expansion in the number of new inquiries circulating. Shippers to Portugal were fairly well engaged in carrying out past orders, and buyers there were showing considerable interest. Trade has not yet opened up to any extent with Spain, and the business offering was still only in respect of occasional cargoes. Some interesting business reported during the week was the sale of some large cargoes of coal and patent fuel to railways in Chile. The general position of coals was unchanged and bituminous smalls continued to provide a strong feature. Outputs of these sorts were fully booked up for some time ahead, and although a keen demand circulated, new business could not be readily arranged. On the other hand, the dry smalls were dull and without support. Most of the sized varieties were heavily stemmed, and offers were only quietly made. All the large descriptions moved off steadily. Good activity was in evidence at the coke ovens, but practically the whole of the production was taken up by contract bookings and supplies were difficult to secure. Pitwood met a steady demand and was unchanged at the official price of 60*s.*

The Iron and Steel Trade.—Favourable conditions were generally in evidence in the iron and steel and allied trades of South Wales and Monmouthshire last week. Practically all the leading works were fully engaged, and production was maintained at a very high level.

NOTES FROM SOUTH YORKSHIRE.

SHEFFIELD, Wednesday.

Iron and Steel.—The increase in production during the past six months has been greater than would have been thought possible. Record outputs are being delivered by all sections; in the production of raw and semi-finished steel, high-efficiency materials, machinery and engineering products generally. Unemployment in this area has attained a new low level. Inquiries in the heavy trades show that the extensive additions to plant, carried out during the depression are not sufficient to meet the present demand for steel products, and new extensions are, therefore, being planned. Steel-producing works are operating at high pressure, and rolling mills, forges, and foundries are all operating at full capacity. In the heavy machinery and engineering branches the general position shows little change as compared with a month ago. While the bulk of production is on war account, an increasing tonnage of steel and finished products is being made available for ordinary commercial purposes. Trade with South Africa in grinding and crushing machinery, dredger parts and buckets, and machines used in the washing of precious metals is not so brisk at the moment, but a satisfactory feature of the medium branches is the progress being made in the production of agricultural machinery and parts on home account. Among the lines in demand are iron and malleable castings, chaff knives, cultivator points, discs (harrow, plough and drill), mower and binder parts, and sections, and springs. Sheffield's output of automobile steel and fittings has been maintained at a high level. Tool steel finds a ready market on inland account, but overseas sales are not so brisk. The tool-making branches are busy, and at the majority of works the outputs are increasing.

South Yorkshire Coal Trade.—The inland demand generally remains very active, as larger tonnages are being sent to industrial concerns, and there is an active demand for house coal.

THE MAINTENANCE OF PUBLIC-SERVICE VEHICLES.—To deal with problems associated with the supply of steel and timber to the operators of public-service vehicles, for maintenance purposes, a liaison panel has been formed by the three principal associations concerned. The members of the panel comprise Major F. J. Chapple, representing the Public Service Transport Association; Mr. J. M. Calder, the Municipal Passenger Transport Association; and Mr. W. Gilden, the Omnibus Owners' Association. We understand that the members of the panel will meet technical officers of the Ministry of Transport with a view to the early disposal of the difficulties of operators as they arise.

NOTES FROM CLEVELAND AND THE NORTHERN COUNTIES.

MIDDLESBROUGH, Wednesday.

General Situation.—The unprecedented makes of iron and steel, supplemented by substantial supplies of American products, are sufficient to ensure adequate deliveries of materials for war-time needs and the continued strict adherence to the regulations, under the control of distribution scheme, promises to permit some increase in the supplies for usual industrial requirements. Deliveries are allocated in strict relationship to the urgency of the requirements. The ample supplies of raw materials and of semi-finished products encourage the hope that it will be possible still further to increase the production of finished commodities.

Cleveland Iron Trade.—The speeding up of the work at the iron foundries is reflected in a larger consumption of pig iron, supplies of which are quite equal to current needs though the shortage of Cleveland qualities is acute. As, however, adequate deliveries of foundry iron from other producing centres are coming to hand, makers of local brands do not regard it as necessary to increase the light intermittent output of Cleveland pig, the recognised market values of which are based on No. 3 quality at 120*s.*, delivered within the Tees-side zone.

Hematite.—The production of hematite is promptly absorbed and considerable imports from the United States are expected to arrive to deal with the heavy and increasing demand. The present delivery obligations of producers practically prevent the acceptance of new orders. Merchants have command of very little iron and their holdings are earmarked for distribution among their regular customers. The heavy and increasing demands for tonnage at the makers' own consuming works continues to call for the bulk of the supply. Hematite users who are dependent on the market for their requirements are pressing for full contract deliveries. Stabilised quotations of East Coast brands are at the equivalent of No. 1 description at 131*s.*, delivered to North of England areas.

Basic Iron.—The make of basic iron fully covers the heavy requirements of producers' adjoining steelworks but leaves no surplus for use elsewhere. The fixed quotation of 113*s.* is nominal!

Foreign Ore.—Consumers of foreign ore have much larger stocks than they held at the outbreak of war and report that imports are satisfactory.

Blast-Furnace Coke.—Little effort is made to carry on business in blast-furnace coke. Local users are very well bought and sellers, though their holdings are exceptionally large, are not inclined to add to their heavy commitments. The price of good medium qualities is put at 33*s.* 5*d.* at the ovens.

Manufactured Iron and Steel.—The steady and substantial output of semi-finished iron and steel, in addition to large purchases of billets and sheet bars from the United States, are sufficient to keep re-rollers and sheet makers fully occupied. The demand for all descriptions of steel is unabated. Most of the large output of heavy steel plates, joists, and sections is passing into use for shipbuilding and constructional work.

Scrap.—Iron and steel scrap is plentiful and some grades are offered in larger quantities than users can accept.

UNITED STATES STEEL INDUSTRY.—According to statistics issued by the American Iron and Steel Institute, the production of open-hearth and Bessemer steel ingots in the United States during August totalled 6,033,037 net tons. This figure is within 2 per cent. of the largest monthly tonnage manufactured in the history of the industry, namely, 6,147,783 tons, which was reached in November, 1939.

LONG AERIAL ROPEWAY IN CENTRAL SWEDEN.—An aerial ropeway of exceptional length is being built in Central Sweden for the purpose of conveying limestone from quarries to a new cement factory. The ropeway is 28 miles in length and it will be capable of transporting 700,000 tons of material per annum. The running, filling and emptying of the 550 skips used is carried out entirely automatically. The construction work is now well advanced; the supporting towers have been erected along the entire route, and the work of placing the cable in position has been begun. Several problems have had to be solved, one of these being the passage of the ropeway across a couple of wide waterways. In one case this has necessitated the suspension of the ropeway at a height of 22 m. (72 ft. 2 in.) to enable ships to proceed freely underneath. Moreover, to carry the line across a lake, concrete towers 45 m. (147 ft. 7 in.) in height have had to be built in the water. The contractors for the work are the Swedish ropeway firm, Messrs. Nordströms Linbaner, and it is anticipated that the installation will be completed by the end of the present year.

NOTICES OF MEETINGS.

IT is requested that particulars for insertion in this column shall reach the Editor not later than Tuesday morning in the week preceding the date of the meeting.

INSTITUTION OF MECHANICAL ENGINEERS.—To-day, 2.30 p.m., Storey's-gate, Westminster, S.W.1. General Meeting. Presidential Address: "Mainly the Port of London," by Mr. Asa Binns. Friday, October 25, 2.30 p.m., Storey's-gate, Westminster, S.W.1. Joint Meeting with THE INSTITUTION OF PRODUCTION ENGINEERS. Discussion on "The Desirability of Acceptance Test Charts for Machine Tools."

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.—To-night, 6 p.m., The Literary and Philosophical Society, Newcastle-upon-Tyne. Annual General Meeting. Presidential Address, by Mr. W. A. Woodeson. *Student Section:* Wednesday, October 23, 6.45 p.m., Bolbec Hall, Newcastle-upon-Tyne. Chairman's Address, by Mr. George Wright, Jun.

INSTITUTION OF ELECTRICAL ENGINEERS.—*North-Eastern Centre:* Monday, October 21, 5.45 p.m., The Newe House, Pilgrim-street, Newcastle-upon-Tyne. Chairman's Inaugural Address, by Mr. W. A. A. Burgess. *South Midland Students' Section:* Wednesday, October 23, 6.30 p.m., The James Watt Memorial Institute, Birmingham. Chairman's Address: "Continuity of Supply," by Mr. D. H. Ray. *Institution:* Thursday, October 24, 2.30 p.m., Savoy-place, Victoria-embankment, London, W.C.2. Ordinary Meeting. Presidential Address, by Mr. J. R. Beard.

INSTITUTION OF AUTOMOBILE ENGINEERS.—*Birmingham Centre:* Tuesday, October 22, 7 p.m., The James Watt Memorial Institute, Birmingham. General Meeting. "Bearing Metals and Their Suitability for Modern Requirements," by Mr. M. Melhuish. *Luton Centre:* Tuesday, October 22, 7.30 p.m., The George Hotel, Luton. General Meeting. "The Application of Gas Producers to Commercial Vehicles," by Mr. Maurice Platt.

MANCHESTER ASSOCIATION OF ENGINEERS.—Saturday, October 26, 2.30 p.m., Engineers' Club, Manchester. "Principles and Applications of Automatic Temperature Control," by Mr. M. J. Gartside.

NOTES FROM THE NORTH.

GLASGOW, Wednesday.

Scottish Steel Trade.—Production in the Scottish steel trade is being maintained on a high level. During the past week the output was sufficient to meet all demands of consumers, and although these represented a very considerable tonnage, a percentage of the material was allocated to the export market. Many urgent inquiries have recently come to hand from overseas buyers. The demands of the shipbuilding industry are still very heavy, and to ensure continuity of operations at the shipyards a considerable tonnage of plates and sections has recently been imported from overseas. There has been considerable business in steel sheets recently. Structural sections are also in steady demand. The raw material position is very satisfactory, as large consignments of steel scrap have been arriving from the United States. The following are the current quotations:—Boiler plates, 15*l.* per ton; ship plates, 14*l.* 3*s.* per ton; sections, 13*l.* 13*s.* per ton; medium plates, rolled in sheet mills, ¼ in. and thicker, 18*l.* 7*s.* 6*d.* per ton; mild-steel black sheets, No. 21-24 gauge, close annealed, 19*l.* 7*s.* 6*d.* per ton; galvanised sheets, plain, No. 21-24 gauge, 23*l.* 2*s.* 6*d.* per ton, and corrugated, No. 24 gauge, 22*l.* 12*s.* 6*d.* per ton.

Malleable-Iron Trade.—There has been practically no change in the state of the malleable-iron trade of the West of Scotland during the week, and a considerable amount of business has been booked. The re-rollers of steel bars are still exceedingly busy and as good stocks of semies are now held the prospects are very satisfactory. The market quotations are as follows:—Crown bars, 15*l.* 2*s.* 6*d.* per ton; best iron, 15*l.* per ton; No. 3 bars, 13*l.* 7*s.* 6*d.* per ton; No. 4 bars, 13*l.* 12*s.* 6*d.* per ton; re-rolled steel bars, tested, 15*l.* 11*s.* 6*d.* per ton, and untested, 15*l.* 8*s.* 6*d.* per ton; angles and tees, 4 in. and under, tested, 15*l.* 1*s.* 6*d.* per ton, and untested, 14*l.* 18*s.* 6*d.* per ton.

Scottish Pig-Iron Trade.—Activity is still very marked in the Scottish pig-iron industry and consumers are constantly pressing for supplies. All the furnaces are in full production, and the output is quickly taken up. Steelmakers are producing a very large tonnage, and it may be mentioned that the demand for foundry iron has improved considerably of late.

THE NIGERIAN RAILWAY.—The total earnings of the Nigerian Railway from January 1 until July 27, 1940, were 631,889*l.*, against 480,613*l.* for the corresponding period of 1939.

REGENERATIVE WORKING ON THE SOUTH AFRICAN RAILWAYS.

(*For Description, see Page* 305.)

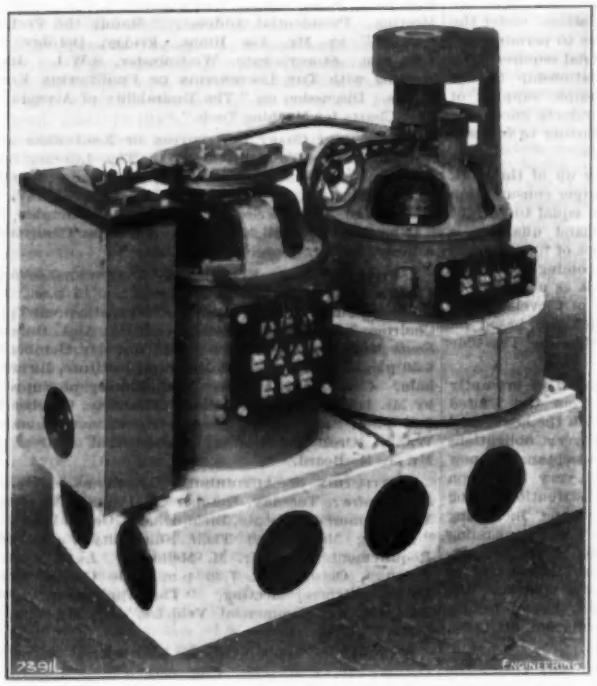


Fig. 11. Phase Shifter and Torque Motor.

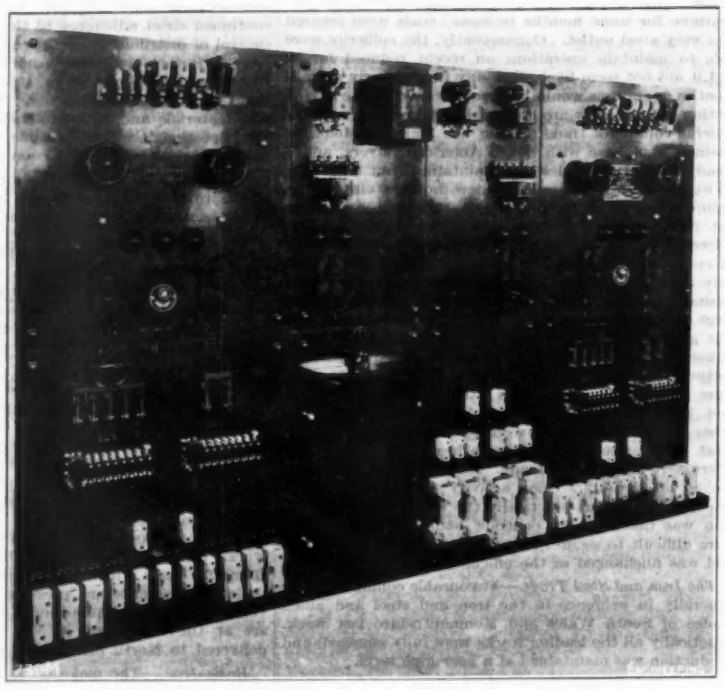


Fig. 12. Low-Tension Control Panel.

ELECTRICITY IN THE UNITED STATES NAVY.

In a paper published in the July issue of *Electrical Engineering*, Mr. Louis Dreller states that probably the three outstanding features of the use of electricity in the United States Navy during recent years are: the introduction of electric propulsion on surface ships, the use of alternating current in place of direct current, and the development of the Diesel direct-current electric drive on submarines. Dealing with the second of these points, he says that, in 1932, it was decided to install alternating-current plant instead of direct-current plant on surface ships, owing to its greater reliability, decreased maintenance, and the reduction in weight and in spare parts it rendered possible. The change also enabled more nearly commercial equipment, particularly induction motors, starters, switchgear and protective devices, which could easily be obtained in war-time, to be used. Finally, it was expected that the improvement in design would be more rapid owing to the widespread employment of alternating current in industry.

In detail, the use of alternating-current generators and motors eliminates commutators and therefore all troubles due to commutation. Squirrel-cage motors are extremely reliable and, except in the large ships, there are relatively few on board that cannot be started with simple direct-on-line switches. The complicated controllers necessary with direct-current motors are therefore eliminated. Transformers, perhaps the most robust of all electrical equipment, are used to obtain the various special voltages required on combatant ships. They are of the single-phase, air-cooled type, have given excellent service, and are now being developed in sizes up to 100 kVA. The practice is to connect them, in delta, so that if one is disabled the lighting system can be operated in open delta. The fact that less maintenance is necessary will become more important as the ships get older and the saving in weight can be conservatively stated as being about 20 per cent. Owing to the reliability of squirrel-cage motors, it has been possible to eliminate the carrying of spare rotors. This item becomes important on a large ship where there may be as many as 400 motors. Another important advantage is that alternating-current motors, transformers and controllers are standardised.

The success of the alternating-current plant depends to a large extent on the proper design of the alternators and associated voltage-regulating equipment. One of the reasons for this is that on board ship the horse-power of many of the motor-driven auxiliaries is large compared with the generator capacity. The magnitude of the current rushes which occur at starting must, therefore, be constantly borne in mind and the distribution arranged so that practically all the induction motors can be satisfactorily started across the line. In order to obtain an alternator economical in size and weight, the inherent regulation at rated load and power factor is generally poor, being about 35 to 40 per cent. This regulation is unsuitable for shipboard use. The success of the alternating-current generator, therefore, depends primarily on the satisfactory operation of the associated voltage regulators. As an example of the difficulties met with and overcome in the development of alternating-current plant, mention may be made of the speed control of motors, the design of light high-speed automatically-operated Diesel engines which can be connected to the line from a cold-start to supply emergency power, the balancing of the phases and short-circuit protection. These problems have all been solved, with the result that the change-over from direct to alternating current has been accomplished without trouble and with great benefit to the Service.

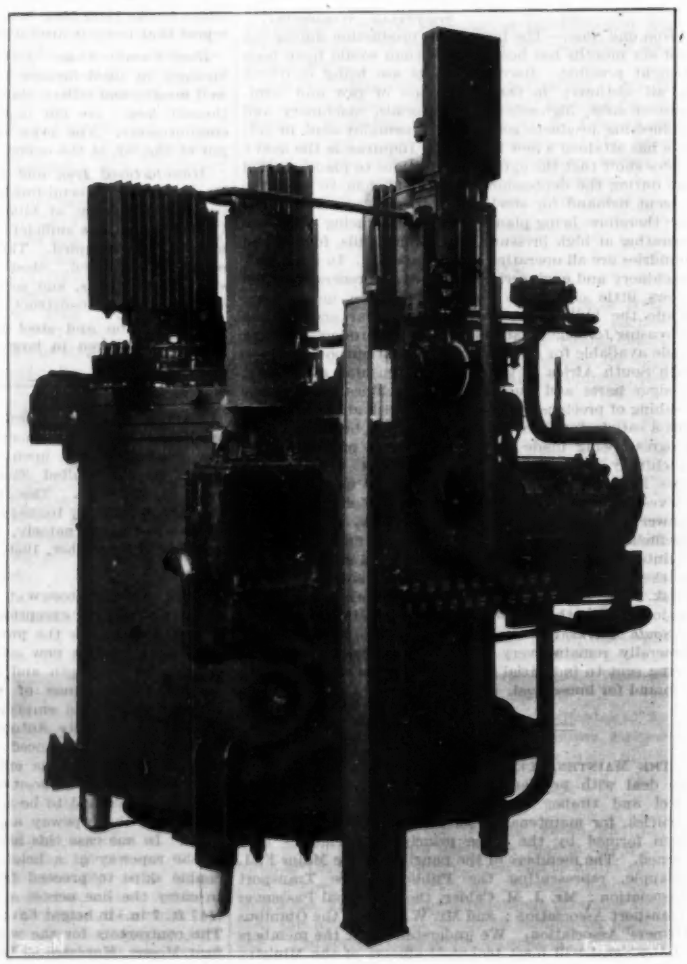


Fig. 13. 1,667-KW, 3,000-Volt Rectifier.

ENGINEERING.

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TIME FOR RECEIPT OF ADVERTISEMENTS.

Classified advertisements intended for insertion in the current week's issue must be delivered not later than first post on Wednesday. Alterations to standing advertisements must be received at least 10 days previous to the day of publication. Passed proofs must be in our hands by Saturday morning, otherwise they will be taken as correct. The Proprietors will not hold themselves responsible for blocks left in their possession for more than two years.

All accounts are payable to "ENGINEERING," Ltd. Cheques should be crossed "The National Provincial Bank, Limited, Charing Cross Branch." Post Office Orders should be made payable at Bedford Street, Strand, W.C.2.

TEMPORARY ADDRESS.

For the duration of hostilities, the Editorial and Publishing business of this Journal is being conducted from 18 and 20, Compton Road, Hayes, Middlesex. The Telephone Number of the Editorial Department is Hayes 1730, and that of the Publishing Department, Hayes 1723. The Bedford Street Offices are open on Fridays only, between 10 a.m. and 5 p.m., for the distribution of the current issue and for retail sales.

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ENGINEERING

FRIDAY, OCTOBER 18, 1940.

VOL. 150. No. 3901.

MECHANISATION ON THE LAND.

"YE generous Britons, venerate the plough!" The line from James Thomson's *Seasons*, which is prominently displayed in the works canteen of, possibly, the oldest firm of agricultural engineers in this country, should not need the stimulus of a world war to exalt it into a national slogan; but it is questionable whether, even after a year of active warfare, the public at large yet comprehends the veneration that is due to the plough as a factor in the national economy, any more than they appreciate the man-centuries of individual experience and observation that are implicit in its many forms and their distinctive contours. It may be that this was true even when Thomson wrote, 214 years ago, for the enclosure of the commons on a large scale had still to come, with its great extension of arable cultivation; but the weight of evidence is against any suggestion that he was indulging in deliberate propaganda, despite his expressed hope, in the same stanza, that the "rich soil" of Britain might "be th' exhaustless granary of a world."

Tempora mutantur. For many years, the world has been the granary of Britain; and although, thanks to the ubiquitous internal-combustion engine, the British countryside is now the reverse of "exhaustless" in a very different sense, not even the accelerating force of an unexampled national emergency is likely to render these islands self-supporting in the matter of agricultural produce within any period for which the war may be expected to last. Nevertheless, the effort is worth making, to approach as nearly to this ideal as circumstances may demonstrate to be feasible. An impoverished and despoiled Europe cannot be expected to re-establish its normal productivity in one season, nor in several, but must depend on charity for immediate needs and on the industries of the manufacturing nations for the means to restore the wastage of its equipment. There will be an ample demand to absorb the world's surplus of food and of feeding stuffs, long after the actual cessation of hostilities; and those countries will be in the best position to render prompt assistance in alleviating this need and meeting the concurrent call for implements of all kinds, which have most fully maintained and developed their own productive capacity in all these respects. Moves to increase the efficiency of British agriculture, therefore, and to improve (and cheapen) the appliances with which it is carried on, have a potential value over and above the requirements of the moment; and the diligence now applied in their study may bear a very close relation to the degree of success with which this nation encounters the initial stress of peace.

It is only fair to assume that these and similar considerations have not been overlooked in official circles, and that the general tendency to organise industry and to plan research on a strictly war basis, and to reduce all possible expenditure on activities that it may seem practicable to defer without detriment, will not be allowed to hamper the work that is steadily proceeding in the various centres of agricultural research. There is encouragement for this belief in a small pamphlet that has been issued recently by the Institute for Research in Agricultural Engineering of the University of Oxford, dealing with the subject of tractor ploughing*. Its 32 pages contain a notably compact, but comprehensive, survey of the art of ploughing with the aid of motor tractors, in "lands" and by the "round-and-round" and "one-way" methods; together with a description of the tractor plough and its adjustments, and some notes on special ploughs and their fittings, *e.g.*, the "digger," "semi-digger," deep-digging and disc types. The various adjustments of the general-purpose plough are treated in some detail, and, taken in conjunction with the thesis on the effective employment of the tractor plough, well indicate the range of its capabilities, and, by inference, the scope that must exist among a diversity of farm lands for the improvement of ploughing technique. In the latter respect, incidentally, both the British manufacturer of such implements and the British users of them enjoy a particular advantage, in that the relatively small size of the country and the variety of its arable acreage provides the individual maker and user with a correspondingly greater variety of operating experience than falls to the lot of the large-scale cultivator overseas. From the manufacturer's point of view, especially, this should prove a definite asset in catering for the needs of the small farmer, and should go some way to offset the difficulty of competing effectively with the mass production of American factories with its accompanying price advantage.

Without minimising in any way the "veneration" due to the plough, however, it may be observed that there are many other items of farm equipment which have ceased to be the concern of the village carpenter and are now definitely engineering products, in addition to those, such as portable stackers, which owe their introduction to the inventiveness of the agricultural engineer; and it is not too soon to consider the trend that may be expected, or that should be encouraged, in their future development. That the mechanisation of agriculture will continue to progress may be taken as assured, if only for the reason that increased labour costs will necessitate a higher standard of production efficiency. An immediate result of the enclosure of the commons, in the early years of the Nineteenth Century, was a considerable increase in the average size of the individual farm. Previously, the majority of farms were little more than what would now be regarded as small holdings, a limitation which seriously restricted the possible scale of farming operations and encouraged the persistence of inefficient tillage. If the fullest benefit is to be derived from mechanical aids to cultivation, it would appear that, either farms must be combined so that each forms an agricultural unit capable of supporting its necessary equipment of machinery, or there must be some extension of the co-operative use of plant. Whether the plant is owned by the farmers jointly, or by a contractor, is immaterial so far as the principle is concerned; but, for the greatest efficiency, it would seem that contracting, if this method is adopted, should be on a much bigger scale than the opera-

* *Tractor Ploughing.* Oxford: The Institute of Research in Agricultural Engineering. [Price: single copies, 6*d.*, including postage.

tions of most of the firms hitherto engaged in it, because the contractor also will be affected by increased first costs, labour costs, and overheads.

It may be worth considering, whether some useful purpose might not be served by a measure of standardisation of certain component parts of agricultural machinery, with a view to cheapening production and facilitating the maintenance of stocks of spare parts. In the case of tractors, of course, the manufacturers have recognised the latter need and have taken all necessary steps to meet it, but there are many other items of equipment to which a moderate degree of standardisation could be applied, without injuring the goodwill in proprietary types. So far as we are aware, this is a branch of mechanical engineering with which the British Standards Institution has not yet dealt, except in so far as its specifications for such universal components as bolts and nuts affect this, in common with most other forms of engineering production. The reason is to be found, perhaps, in the proviso that the Institution may not itself initiate proposals for standardisation, but must await a request from persons or bodies, representative of the interests involved; such a proposal might well be made, however, by the Ministry of Agriculture and Fisheries, or by the Royal Agricultural Society.

It is to be expected that any such suggestion would meet with a certain amount of opposition from those who hold that the farmer is the best judge of the appliances most suitable to his own local conditions, and that these conditions are probably responsible, whether he is aware of it or not, for the detail design of the implements in customary use in each district. Up to a point, no doubt, this is true; but the relative cheapness and availability of stock machines listed by the leading manufacturers have done much to break down the local conservatism which found its expression in a rigid adherence to older types evolved by generations of local craftsmen, working with the materials that came most readily to hand, to proportions and details of design modelled on the plant already in use in the neighbourhood. Such methods amount to a virtual standardisation, and their results are found most strikingly displayed, perhaps, in the equipment used by deep-sea fishermen of the older generation. As steam has enabled the fishing fleets to work at greater distances from their home ports, however, these local peculiarities of practice are tending to disappear; and a similar tendency has been in evidence on land, since motor vehicles have come into general use in the farming community. The combination of types, to enable a reduced number of patterns to be adapted to the needs, or fancied needs, of different districts, follows as inevitably as local dialects tend to merge into a common standard of speech; and it is for the manufacturers to consider whether the process can be accelerated with advantage, and, if so, to what extent.

There is one respect in which it may be advisable for agricultural engineering practice not to press too closely on the heels of scientific advances which other branches of engineering manufacture do not hesitate to adopt at once. The facilities for emergency repairs are seldom so complete and up-to-date as those available in a large industrial centre, and it is desirable that the design and the materials of parts liable to need quick renewal, possibly at a time when all concerned are working against the clock, should be such as not to demand special and intricate tooling or other processing. It is improbable that the benefit to be derived by using some alloy of highly distinctive physical properties will outweigh the handicap of having to wait a week for a replacement, because the local shop has only stock mild-steel bars and these cannot be made to serve. Old-established makers of agricultural machinery would be most unlikely to overlook so obvious a detail; but the increasing application of scientific research in an industry such as agriculture, is almost certain to give rise, sooner or later, to occasional innovations based on book-knowledge rather than experience. A few such incidents would do more to retard the agriculturalist's appreciation of scientific method, as applied to his engineering problems, than ninety-and-nine successful applications would do to build it up.

ELECTRICAL INSTALLATIONS AND EARTHING.

In Telford's description of engineering as the "art of directing the Great Sources of Power in Nature for the use and convenience of man," the operative word, obviously, is "directing." Not only must the forces involved be constrained to pass along a given path, but, equally positive means must be adopted to prevent them straying therefrom. The two things are not necessaruly synonymous. In the case of such of the usually employed agents as steam, gas, oil and water, the latter condition is not difficult to fulfil, for their escape from preordained channels can be detected by the senses of sight, smell, hearing or touch, either alone or in combination, and detection by some simple means dependent on those senses is therefore easy. With electricity the position is altogether different, which explains why in all countries a mass of regulations has grown up, the object of which is to ensure that electricity shall generally be utilised in such a way that no danger either to personnel or material shall result. Electrical installations lend themselves to control of regulations and are, therefore, a temptation to legislators.

As might be expected, the form, substance and application of electrical regulations varies in different countries. In Germany, even before the advent of Hitler, regulations covering every branch and application of electricity supply had been prepared by the Verband Deutscher Elektrotechniker and other bodies, and were made compulsory for all classes of installation. It is not suggested that the standard required was impossibly high, but what was stipulated had to be provided. The same is true in certain other more democratic countries, notably Canada and New Zealand, where a rigid code, and enforced compliance with it, have combined to produce a high standard, both of material and workmanship. A considerable, if not an absolute, degree of safety is therefore ensured, and, if an accident can be traced to a failure to observe the appropriate regulations, the culprit can be brought to book through the processes of the law. In this country the position is somewhat different. Regulations issued by the Electricity Commissioners under the Electricity Supply Acts secure the safety of the public so far as concerns the transmission and distribution systems, whether underground or overhead, while similar regulations issued by the Home Office under the Factory Act have covered the equipment installed in factories. There are also rules, with a compulsory application, dealing with the use of electricity in mines, while tramways are looked after by the Minister of Transport. In all these cases compliance is no onerous task. In addition, however, there are other codes of rules, which, not being compulsory, tend to set a standard of excellence rather than to impose a working criterion. Among the most important of these are the wiring rules issued by the Institution of Electrical Engineers. As, however, they are not enforceable, the curious position arises that it is possible to connect to the mains a domestic installation the standard of which is not only below that laid down in the rules but may even approach the border line between safety and danger. A further result is that the standard set by these regulations is so high that it would probably have to be modified if the suggestion to make them compulsory, which is often proposed, were to be adopted.

The position in the United States illustrates this point. The National Electrical Safety Code, a fifth edition of which has been issued recently, is compulsory in its application, but for that reason, no doubt, it is much more general than the rules of the Institution of Electrical Engineers. Indeed, it corresponds more closely with those issued in this country by the Home Office, which, as we have said, cover factory installations only, but are compulsory in their application. It is laid down, for instance, that "all electric supply equipment shall be of such construction and so installed and maintained as to reduce life hazard as far as practicable"; and, though this general requirement is amplified by insisting on the need for constant inspection, the guarding of moving and live parts and the provision of protective earthing, a comparison with the very much more detailed rules of the Institution of Electrical Engineers, will show that, while compulsion may have its disadvantages, curiously enough, it may lead, in some cases, to a greater freedom in practice.

It is not altogether surprising that an exception to this rule is to be found in the section relating to earthing. To earth non-current-carrying metal parts of electrical apparatus is now the almost universal practice in all countries, though with the production of insulating materials of greater mechanical strength this statement is becoming modified to some extent, at least as regards the smaller apparatus. It is, however, easier to lay down, as the Electricity Commissioners do, that such non-current-carrying metal parts shall be "connected with the general mass of earth in such manner as will ensure an immediate and safe discharge of energy," than to ensure that such a connection shall have the desired effect, for, as we pointed out recently, with the increase in the size of transmission and distribution systems, this apparently simple condition is not always easy to fulfil, for the reason that the resistance of the "earth" may be high in comparison with that of the system itself, and, in certain circumstances, the protection afforded may become fallacious. It is this state of affairs which has led the British Electrical and Allied Industries Research Association to investigate the problem of earth-electrode resistance and has caused such bodies as the Hydro-Electric Power Commission of Ontario to take drastic steps to ensure that the earths are performing the duty for which they were designed.

In this connection it is interesting to note that the American rules lay down that the combined resistances of the earthing wire and the connection with the ground shall not exceed 3 ohms for water-pipe connections, or 25 ohms for artificial earths. Where it is impracticable to obtain the latter figure with one electrode, two or more must be provided, spaced at least 6 ft. apart. That such a condition is not always easy to fulfil is shown by experiences in Ontario, where 23,164 earths were tested with the result that 17,359 had to be supplemented by the provision of extra electrodes or by treating the ground with common salt in order to bring the resistance down to the desired figure. As pointed out by Messrs. E. Fawsett, H. W. Grimmitt, G. F. Shotter and H. G. Taylor, in a paper read before the Transmission Section of the Institution of Electrical Engineers earlier this year, earths can also be improved by driving small-diameter copper rods as far as possible into the soil. For instance, one particular series of tests indicated that, while the resistance of an electrode was 110 ohms when it was driven to a depth of 3 ft., the resistance became as little as 2 ohms when the depth was increased to 36 ft. If these results are to be taken as representing modern practice, it would seem that some modification of the American rules is desirable. In dealing with this point, they seem to express a preference for plate electrodes, but lay down that, where pipes or rods are used, they shall not be less than $\frac{3}{4}$ in. in diameter, where they are made of iron or steel, or less than $\frac{1}{2}$ in. where they are of non-ferrous metals. They should be in one piece, and should be driven to a depth of at least 8 ft. On the other hand, the British investigations, to which we have drawn attention, recommend a smaller diameter and driving to a greater depth. It would be a good thing if this discrepancy could be cleared up, for both technical and practical reasons, for this question of earthing is probably the most important that yet remains to be decided and codified.

For the rest, it may be allowed, with fair certainty, that, as regards electrical installation work, theory and practice now form a satisfactory combined whole. That being so, perhaps a plea might be made that in the near future some real attempt should be made to attain greater simplicity both of statement and requirements. Complication is not in itself a virtue. It is often a confession of weakness. With the present state of knowledge, it should be possible to cut away from the regulations everything that is not absolutely essential, thus benefiting the manufacturer, the contractor and the user.

NOTES.

TELEPHONE DEVELOPMENT OF THE WORLD.

THE Chief Statistician Division of the American Telephone and Telegraph Company have compiled a number of interesting figures regarding the telephone development of the world on January 1, 1939, and these are published in the current number of *Electrical Communication*. Just over 52·6 per cent. of the total number of telephones, viz., 41,090,347, are to be found in the North American Continent, 48·56 per cent. being in the United States and 3·31 per cent. in Canada. Of the total, 21,900,000 are automatic telephones, 42 per cent. of which are in the United States. Europe possesses 37·25 per cent. of the total, the most highly developed country being Germany, with 10·09 per cent., followed by Great Britain with 7·84 per cent., and France with 3·87 per cent. Asia has 4·65 per cent. of the total, Oceania 2·32 per cent., while Australia is represented by 1·54 per cent., and South America by 2·18 per cent. Africa has only 0·99 per cent., of which over half are in the Union of South Africa. The development can be stated in another way, by saying that there are 174,548,000 miles of telephone wire in use in the world, of which 56·94 per cent. are in North America, 10·31 per cent. in Europe, and 4·07 per cent. in Oceania. In this connection, it is interesting to note that there are only 6,730,500 miles of telegraph wire, of which 41·89 per cent. are in North America and 33·39 per cent. in Europe. Washington is the most highly developed city in the world from the telephone standpoint. It has 40·14 instruments per 100 of population, but is closely followed by San Francisco with 38·53 and by Denver with 32·44. In Canada, the corresponding figures are 26·34 for Toronto and Vancouver, and 19·79 for Ottawa. In Europe, Stockholm leads the way with the high figure of 38·28, followed by Berne with 26·01 and Copenhagen with 23·91. London has 17·81, Helsinki 16·83, Paris 15·45, and Berlin the surprisingly low figure of 13·83, while The Hague has 10·67 and Rome has 9·57. Tokio has only 4·5.

EXPORT TRADE WITH CANADA.

The extreme importance of methodical and exhaustive market study, which was emphasised throughout our recent series of articles on trade possibilities with Latin America, was also a leading theme in the address on "Canada and United Kingdom Export," which Mr. Nugent M. Clougher delivered in London on October 9, at a meeting of the Institute of Export. His remarks related principally to general trade, without particular reference to engineering products, but many of them were certainly applicable in this field—for example, his consideration of the question, "Does it pay to manufacture specially for Canada?" and his observations on tariffs, as affected by present manufacturing conditions in the United Kingdom. The answer to the problem of special manufactures for the Canadian market, as might be expected, was largely conditional, so much depending on the nature of the product. Alterations requiring heavy expenditure on jigs, dies, or the setting of press tools might not be justified by the volume of immediate trade with Canada alone, but, as Mr. Clougher pointed out, they might well have the effect of rendering the product more acceptable in other American markets, notably in the United States. On the subject of tariffs, the speaker observed that the United Kingdom exporter enjoyed a definite advantage in sending goods to the Dominion, due to the British preferential tariff, which is the lowest of the three tariffs affecting Canadian import trade. The intermediate tariff forms the basis of trade with countries with which Canada has commercial treaties (of which the principal one is now the United States); and, finally, there is the general tariff, applying to countries having no trade agreements with Canada. Tariffs, however, are based on the normal home selling price of the goods in the country of origin, a feature which imposes a certain hardship on the United Kingdom manufacturer under war conditions, because the increases in manufacturing charges automatically operate to increase the duty, *pro rata*. In some cases, Mr. Clougher stated, this disability had made it necessary to cancel export trade with the Dominion; if the Canadian Government could see their way to assess the duties on pre-war selling prices in the United Kingdom, and not on the inflated values brought about by the war, such an action would be of real help in expanding trade within the Empire and, in consequence, increasing the credits available abroad for the British Treasury.

COMPENSATION FOR AIR-RAID DAMAGE.

At the beginning of the war the Government, acting upon expert advice, found it impossible to prepare an insurance scheme from which compensation for air-raid damage to buildings could be drawn. The most that could be done was to permit sufferers to borrow money free of interest to do the necessary repairs. Even so, these loans were based on the prices ruling in May, 1939, since when costs have risen considerably. The position was, therefore, that the difference had to be made up without public assistance, a task which would often be difficult and frequently impossible to perform. In spite, however, of the continuous attacks to which this country has been exposed from the air during the past few weeks, the damage both to life and property, as the Prime Minister has pointed out, has been much less than was anticipated. It has, therefore, been possible to introduce a scheme of compulsory insurance against air-raid damage, and a Bill dealing with the subject has been promised for this week, though it has not appeared at the time at which we go to press. It seems likely that a premium of about 2*s.* 6*d.* per cent. on the capital value of the buildings will be charged, though power may be taken to enable the Treasury to vary the rate if necessary. The new measure will make the position more satisfactory, as compensation will no longer be a question of somewhat grudging charity, but a matter of right. Though probably the simplest way of collecting the premiums will be by an addition to the property tax, it is to be hoped that the assistance of the insurance companies will be enlisted to assess risk and to deal with claims. They have the expert knowledge, so that another Government department, including the usual Civil Service element, is quite unnecessary. It is satisfactory, too, to be able to report that, following on negotiations with the Amalgamated Engineering Union, compensation for loss of tools exceeding 1*l.* in value will be payable, up to a maximum of 50*l.*, to men whose incomes are between 250*l.* and 400*l.* per annum.

STATISTICS OF ELECTRICITY SUPPLY UNDERTAKINGS.

By the terms of their appointment, the Electricity Commissioners are under the obligation to collect complete data of the operation and financial position of the supply undertakings in this country. In normal times, these are published in volumes, the bulk of which is as impressive as their utility is manifest. At the beginning of the war, however, it was decided, for good reasons, that the issue of further volumes should be deferred, and nothing has happened to render any change in this course advisable. The Commissioners, nevertheless, consider that it is important that the continuity of the main statistics should be preserved so that publication can be resumed after the war, and accordingly trust that all undertakings will continue to maintain their statistical records as fully as circumstances permit. On the other hand, after consultation with the Joint Committee of the Electricity Supply Associations, they have reduced the information required to be submitted for 1939-40, and have sent a circular to all undertakings requesting the submission of the return in its abbreviated form not later than Monday, November 11. The return requires such information as loans or capital raised, capital expenditure on generators, transmission, distribution and apparatus on consumers' premises, revenue from lighting, heating, cooking, power, public lighting, traction and bulk supplies, expenditure on generation, energy purchased and rates, and details as to the allocation of the gross surplus. In addition, the number of staff and workmen, the total salaries and wages, number of consumers and details of the tariffs must be given, as well as data regarding system and voltages, electricity generated, purchased and sold for various purposes, maximum load, load factor and fuel consumption. A second form has also to be filled in by undertakers who operated any of their generating stations under the direction of, and who disposed of their output to, the Central Electricity Board during the year, and who obtained a supply in bulk from the Board for the purposes of their own undertaking.

SHIPBUILDING AT DUBLIN.

In the 76 years that have passed since the completion of the first iron ship to be constructed at Dublin, the shipbuilding industry of the port has experienced numerous vicissitudes, usually adverse, and the more regrettable because, in retrospect, it can be clearly seen how the more severe of them might have been avoided if the local labour organisers had been less shortsighted. The history of the Dublin Dockyard Company, from 1901 to 1923, has been well told by Mr. John Smellie, one of the joint managing directors, in a book which was reviewed on page 352 of our 140th volume. Mr. Smellie showed clearly that, although it was Alderman William Doyle, then president of the Dublin Trades Council, who instigated the revival of Dublin shipbuilding in 1901, the voluntary liquidation of the company in 1923 was directly due to the action of the local unions in repudiating the original bargain with the company that wages and working conditions generally should conform to those on the Clyde. The premises and plant were bought in 1923 by Messrs. Vickers Limited, who formed a subsidiary company, Vickers (Ireland), Limited, to operate the yard. By strenuous efforts, and the aid of sundry contracts for such miscellaneous steelwork as railway bridges and the framing of the Dublin Theatre Royal, they contrived to keep the establishment open throughout the prolonged depression; but circumstances were too strong for them also, and the yard was closed at the end of 1937. Since then it has remained closed, although care was taken by the Port authorities to keep most of the plant in good order. The foresight is now receiving a measure of reward, as, we understand, arrangements have been made by Mr. W. R. Murdoch, M.I.N.A., formerly of Amsterdam, to reopen the yard for both building and repair work. The reception of the news in Dublin and district has been extremely favourable, and there is little doubt that, in present conditions, a steady flow of work can be obtained; while the advantages of having such facilities available in the port seem so obvious that there is ground for the hope that the mistakes of the past will not be repeated in the difficult period of post-war readjustment.

UNIVERSITY COLLEGE LIBRARY.

The recent announcement that about 100,000 books and pamphlets have been destroyed by fire and water, following a direct hit by a German bomb on the library of University College, London, will accentuate the fears of serious students throughout the world for the safety of other famous collections, the size of which makes it impracticable to remove them bodily to safer quarters for the duration of the war. London is particularly rich in such specialised collections and although many of the more modern works of a general character, and the files of technical periodicals, might be replaced in course of time, it would be difficult to make good the loss of some of the former private collections, painstakingly gathered by scholars of world repute and deposited in the great libraries for the benefit of posterity. The library of University College contained many such, in addition to books belonging to various small societies which possess no premises of their own, but whose members possess personal associations with the University which make the College a convenient centre for their deliberations. The interests represented in the damaged library, which has lost rather more than a third of its contents, are rather those of the arts and *belles lettres* than science, but the scientific sections were not negligible, and included many early works on chemistry, mathematics, physics, engineering and the history of science.

THE ACOUSTIC AIR-JET GENERATOR.

In the year 1916, Professor Hartmann, of Copenhagen, while exploring with a Pitot tube the distribution of total head in a high-speed jet of air, observed that the pressure along the axis of the jet underwent a cyclic variation with distance from the discharge nozzle. This so-called Pitot curve, shaped like a sine wave of diminishing amplitude, comprised successive wavelengths along which the pressure was alternately falling and rising, and it was found that the intervals of rising pressure were unstable. When for instance, the pressure over these regions was explored with a wide Pitot tube, unstable readings were obtained, indicating that the air in the jet alternately entered and was discharged from the tube with a regular frequency. The same phenomena occurred when the open end of a hollow vessel or "oscillator" was mounted in a rising pressure region of the air jet, the result with this arrangement being the production of vigorous sound waves varying in frequency according to the volume of the oscillator and the size of its open end. Judging that, in addition to its intrinsic interest, many valuable technical applications would be found for an acoustic generator based on this principle, Professor Hartmann has spent several years in developing his apparatus and studying its characteristics, assisted by three other physicists and supported financially by the Carlsberg Foundation, the Örsted Fund, and other Danish endowments.

The generator was described and demonstrated by Professor Hartmann at the Blackpool meeting, in 1936, of the British Association, a lengthy illustrated report of his paper being shortly afterwards reproduced in ENGINEERING.* The final account of the work, now issued in the English language as No. 4 of the Ingeniörvidenskabelige Skrifter,† covers a good deal of experimental research hitherto unpublished in English and presents complete data and theoretical analyses immediately useful to research workers in acoustics. The equipment used to obtain these data included several different forms of generators fitted with precise means of adjusting and measuring the dispositions of its separate parts, and an acoustic cabinet, lined with sound-absorbing material, for the exploration of sound-wave intensities. Sound-pressure intensities were measured by Rayleigh discs and by a form of indicator incorporating a Westphal balance. An interesting feature of the acoustic generator is that, with an output of 50 watts, its radiation gives rise to a sensation of heat in a hand held at a few centimetres distance —a sensation which becomes painful if the output exceeds 100 watts. This observation suggested that thermal methods might serve to measure the rate of flux of acoustic energy, and a number of indicators based on this principle and embodying thermocouples were developed and tested. Interesting experiments were also made with instruments designed to measure acoustic energy in terms of the differential air pressure produced between the opposite sides of a disc, pierced by a pin hole, mounted in the acoustic field of the generator.

By means of this, and other appropriate apparatus, the characteristics of the Hartmann generator—the wavelength, intensity, distribution and efficiency of its radiation—were thoroughly explored in relation to its dimensions and mode of operation. Most of this work was carried out with generators in which the diameters of the jet and the oscillator varied from 2 mm. to 6 mm., the jet velocities being due to pressures ranging up to 5 atmospheres. Within these limits the fundamental wavelength of the sound generated was found to be from 5 to 6 times the diameter of the jet, while the efficiency of the apparatus, *i.e.*, the ratio between the total flux generated and the power required to maintain the jet, amounted to some 5 per cent. The results now available are adequate for the design of generators covering the frequency range from about 5,000 cycles up to 50,000 cycles per second. The polar distribution of the radiation is, of course, a complex function of the external shape of the jet nozzle and oscillator, an interesting point in this connection being that the maximum flux is not always in the plane normal to the axis of the generator, and that circular discs or disc-shaped extensions fitted to the oscillator give rise to pronounced peaks in the polar distribution curves.

The Hartmann generator is a convenient, nominally "point," source of sound for the study of interference and diffraction phenomena. The wavelength of its own radiation, for example, was measured by the well-known reflection method, a movable plane mirror being mounted on one side of the generator while a Rayleigh disc on the opposite side served to indicate maxima and minima in the displacement amplitudes of the interfering sound waves received directly and after reflection. By an extension of this principle, spectral analyses of the generated sound were carried out and subsequently compared with results obtained from an acoustic grating spectrograph which consisted of a row of rectangular bars mounted in a rotatable frame. In a series of associated experiments, a valuable degree of directional control over the generated sound was achieved by means of a parabolic mirror, and, to a less extent, by a conical trumpet. With the former arrangement, for example, the angular distribution of acoustic radiation was strikingly restricted, while the maximum rate of flux energy was correspondingly increased, in some cases to over 200 times that measured without the mirror. The best results were obtained when the focus of the mirror was midway between the nozzle and the oscillator, the latter being nearer the mirror because the main part of the radiation (as revealed by the polar distribution studies) is directed away from the jet pipe.

These mirrors, of course, were smooth, solid boundaries for reflecting sound. A more interesting mirror, mentioned and illustrated in the earlier article in ENGINEERING, was observed by one of the investigators to occur at the stationary Riemann wave formed when the air jet from the nozzle impinges upon a plane wall or upon the oscillator of the Hartmann generator. The front of such a stationary wave is characterised by sudden and considerable changes in the velocity, pressure, density, temperature and other properties of the flow of air. These changes occur within a very thin layer, the thickness of which is of the same order of magnitude as the free path of the air molecules. The wave front must thus reflect light very effectively and it does, in fact, act as a brilliant mirror. The shape of the mirror, being that of the stationary wave front, varies according to the relative disposition of the jet and the wall or oscillator against which it impinges, but it commonly appears as a brilliant disc when viewed at a small angle from the axis of the jet, or as a thin, curved arc or line when viewed from the side. It was found that this Riemann mirror, when illuminated, yielded a simple means of visualising the oscillations of the air in the generator, the effects of varying distances between the nozzle and the oscillator, for instance, being to make the mirror, viewed edge-on, appear either as a steady bright line or as a less brilliant band of width corresponding to the amplitude of the sound waves generated. By the aid of suitable auxiliary apparatus, oscillograms of the vibrating wave-front were photographically recorded over a range of generating conditions, thus enabling the frequency of the waves at the actual source of sound to be measured and the wave-form to be established as being very closely sinusoidal. Finally, the Riemann mirror has been used as a basis for measurements of total acoustic radiation, a massive and precise form of generator, provided with means for exploring the pressure and temperature conditions in the oscillator, being specially designed for the purpose.

As will be apparent from this cursory survey of the work of Professor Hartmann and his collaborators, the academic or fundamentally scientific aspects of the generator and its mode of operation have been adequately covered. Except for its obvious utility as a source of controllable sound for acoustic research, however, the authors, in this paper, put forward no specific suggestions for applying it usefully in engineering or other industries, although in previous accounts they have discussed its possibilities for precipitating smoke and dust in the atmosphere and for producing supersonic vibrations which might be employed for testing the quality of materials. Its potentialities as a means of communication, and otherwise of transmitting supersonic energy through the air, will also warrant the closest consideration. But over the audible range of frequency the Hartmann generator is faced with the opposition of a host of already firmly established competitors, and the reticence of its inventors on new ways and means of augmenting the sufferings of a noise-tormented world has much to commend it.

* Vol. 142, page 491 (1936).

† *The Acoustic Air-Jet Generator*, by Jul. Hartmann, in co-operation with Peter and Elisabeth v. Mathes and Freimut Lazarus. Ingeniörvidenskabelige Skrifter, 1939, Nr. 4. Akademiet for de Tekniske Videnskaber og Dansk Ingeniörforening.

INSTITUTION MEETINGS.

In the normal course of events, the numerous technical institutions would now be resuming their winter activities. Last winter, it will be recalled, all evening meetings (which, customarily, would form the great majority of such functions) were cancelled as a result of the official ban on large gatherings in regions thought to be liable to air attack. Subsequently, this restriction was relaxed, although in effect the inconvenience of travelling in the black-out operated to produce much the same result. This winter, meetings are not to be abandoned altogether, in spite of the much intensified scale of the German air offensive, especially in the London area; a circumstance which is doubly satisfactory, both in view of the undoubted utility of the meetings themselves, and as evidence that the enemy's efforts to paralyse this nation's normal activities are still very far from achieving their object.

At the present time, not all of the institutions and societies concerned have published their full programmes, but such information as is to hand indicates that strenuous endeavours are being made to maintain the several series of professional papers, even though, in some cases, it is being found desirable to arrange for them to be discussed by correspondence. The Institution of Civil Engineers has prepared a full programme, although the time of meeting is to be advanced from 6 p.m. to 1.30 p.m., in order that the members may meet for luncheon beforehand. The Institution of Mechanical Engineers has made a definite announcement only in connection with the meetings to be held on October 18 and October 25, the time of which is to be 2.30. The former meeting is to hear the presidential address of Mr. Asa Binns, entitled "Mainly the Port of London," and will be preceded at 1.0 p.m. by an informal luncheon at the Royal Empire Society. The meeting arranged for October 25 is being held jointly with the Institution of Production Engineers, to discuss "The Desirability of Acceptance Test Charts for Machine Tools." The informal meetings announced for October 11 and November 8 were cancelled, and no particulars are available regarding the remaining dates in the draft programme.

A year ago, the Institution of Electrical Engineers decided not to hold meetings, but to circulate all papers already accepted for presentation and to invite written discussion upon them. During the forthcoming session, the same procedure will be adopted. A limited number of advance copies of papers will be available at monthly intervals and will be supplied to members on application. One meeting is to be held, however, on Thursday, October 24, when the President (Mr. J. R. Beard) will deliver his address. Many of the provincial technical institutions and societies, whose members are likely to be less affected by transport difficulties than those in the London district, who usually have longer distances to travel, will approximate more closely to their normal practice; and, in view of the importance of maintaining such activities as fully as possible, it is to be hoped that other societies, which have not yet reached a decision on the point, will adopt the same course wherever practicable.

PRACTICAL BLAST-FURNACE MANAGEMENT IN SOUTH AFRICA.*

By R. R. F. WALTON.

(*Concluded from page* 300.)

Preparation of the Furnace.—The following method of preparing and blowing in the furnace has been standardised in South Africa :—When the brickwork is finished and the top gear in position, the tuyere coolers are rammed up from the inside with ground fireclay and brick, thoroughly packed in. A fire is then made on the hearth, the cooler apertures being bricked-in with a loose brick in each to allow of adjusting the draught. In the case of the Iscor furnaces, where there is always one in blast and the gasholder maintains continuity of pressure and supply, blast-furnace gas is led into the fire through a 3-in. pipe after a couple of days. At Newcastle, where there is only one furnace, the fire is fed with coke and gently blown with compressed air. This drying is continued for from 14 days to 21 days, and meanwhile all the cooling plates are carefully pointed up on the outside with refractory cement.

After firing has finished and the brickwork has cooled down, about 3 in. of coke and tar mixture is rammed on the hearth in the shape of a saucer, to cover the horizontal joints where the brickwork is corbelled back to the same diameter as that of the wall of the well.

TABLE IV.—*Typical Filling Charge for an Iscor Furnace.*

Set 1.—			
6 rounds, each of 4 skips of coke,		at 2,500 lb. per skip.	
No ore or dolomite.			
Set 2.—			
5 rounds, each of	4 skips of coke	at 2,500	,, ,,
	1 skip of dolomite	2,000	,, ,,
	1 skip of limestone	2,000	,, ,,
To be charged :	2 coke plus 1 dolomite on first bell.		
	2 coke plus 1 limestone on second bell.		
Set 3.—			
On first bell :	4 rounds, each of 4 skips of coke,	at 2,625	,, ,,
On second bell : 1 skip	Thaba ore	1,250	,, ,,
	dolomite	1,100	,, ,,
1 skip	Pretoria ore	1,250	,, ,,
	limestone	1,100	,, ,,
Set 4.—			
On first bell :	4 rounds, each of 4 skips of coke, at	2,625	,, ,,
On second bell 1 skip	Thaba ore	2,000	,, ,,
	dolomite	1,150	,, ,,
1 skip	Pretoria ore	2,000	,, ,,
	limestone	1,150	,, ,,
Set 5.—			
On first bell :	4 rounds, each of 4 skips of coke, at	2,625	,, ,,
On second bell : 1 skip	Thaba ore	2,800	,, ,,
	dolomite	1,400	,, ,,
1 skip	Pretoria ore	2,800	,, ,,
	limestone	1,400	,, ,,
Set 6.—			
On first bell :	4 rounds, each of 4 skips of coke, at	2,625	,, ,,
On second bell : 1 skip	Thaba ore	4,100	,, ,,
	dolomite	1,650	,, ,,
1 skip	Pretoria ore	4,100	,, ,,
	limestone	1,650	,, ,,
Set 7.—			
On first bell :	4 rounds, each of 4 skips of coke, at	2,625	,, ,,
On second bell : 1 skip	Thaba ore	5,000	,, ,,
	dolomite	1,900	,, ,,
1 skip	Pretoria ore	5,000	,, ,,
	limestone	1,900	,, ,,
Set 8.—			
On first bell :	4 rounds, each of 4 skips of coke, at	2,625	,, ,,
On second bell : 1 skip	Thaba ore	5,500	,, ,,
	dolomite	2,000	,, ,,
1 skip	Pretoria ore	5,500	,, ,,
	limestone	2,000	,, ,,

A 6-in. pipe is placed in the tap-hole, about 3 ft. inside the well and extending about 4 ft. down the tapping-trough. This is rammed around with tap-hole clay from inside and outside. Four 1¼-in. holes are drilled in the pipe so that it can be turned to keep it free in the hole and to withdraw it later. Coke is then thrown in by hand to the level of the bottom of the tuyere arches, and all tuyeres but one are put into position. Three sacks of coke, one on each side and one on top, are put around each tuyere to protect it when filling begins from the top. Likewise old sleepers are placed against the bosh wall to protect the brickwork. The last tuyere is now put in place, and a little kindling-wood and shavings are put in front of the nose of each tuyere. The blow-pipes and goose-necks are now fitted, and filling begins from the top. Table IV indicates a typical filling charge for one of the Iscor furnaces.

When the furnace is full to about 20 ft. from the top, the distribution is examined by getting into the furnace through the big bell, which should be propped open. Care must also be taken that the water-seal or other valve isolating this furnace from the common cool-gas main is not leaking. Filling proceeds to 5 ft. below the big bell, and the furnace is ready for lighting. The water supply to the various cooling members is adjusted, each tuyere and tap-hole is lighted with hot bars and hot blast is put on at about 10,000 cub. ft. per minute for half-an-hour, the gas escaping through the bleeders and a little steam being turned into the main dust-catcher. After half-an-hour the blast is taken off, the tuyere lids are opened and the furnace is allowed to "draught" for 24 hours. Blast is then put on again, and the gas is ignited at the pipe in the tap-hole and allowed to burn there for about 2 hours. The pipe is then withdrawn and the tap-hole plugged with the mud-gun. The gas is now of sufficient volume and quality to be put into the system. The water-seal at the outlet of the Vortex is emptied, and each vessel and main is purged in turn until the gas is right through the system, when the valve to the clean-gas main is opened and the operation is complete. The history of this "blow-in" is represented in Table V, below.

General Operation.—The filling and distribution require careful watching and checking. Charging must be regular and the furnace kept as full as possible—to about 3 ft. below the big bell when in the open position. In addition to the automatic stock-line recorder, two other trial holes are provided, and it is customary to check up on these regularly to ensure that the distribution is even and the stock is level in the furnace. The coke charge is as large as possible, consistent with the capacity of the bell and hopper, as it is found that most furnaces work better the bigger the coke charge. At Iscor the coke charge is 10,500 lb. charged in four skips on the first bell, followed by two skips of ore and one of flux on the second bell. At Newcastle the coke charge weighs 4,800 lb. charged on the first bell in six barrows, followed by six barrows of ore and three of flux on the second bell.

It is the author's practice, so far as possible, to keep both the burden and blast volume constant for any one grade of iron and to make all necessary adjustments by alteration of the blast temperature. For any furnace there is an optimum blast volume, which can only be determined by experiment. When this has been fixed the burden is adjusted so that normally there is ample reserve of blast temperature in hand. The foremen have only to adjust this to keep the furnace on a constant grade of metal. When making basic metal for the open-hearth plant the furnaces often run for months on end without alteration of blast volume or burden, keeping the product constantly between 0·5 per cent. and 0·9 per cent. of silicon. The practice is admittedly more difficult where the use of several different ores necessitates changes of burden, but the practice often met with of changing the blast volume to meet variations in slag composition and furnace conditions is obviously unsatisfactory.

TABLE V.—*History of the "Blow in" of an Iscor Furnace.*

Nov. 24,	8.30 A.M.	Furnace lit up. Draughting until 8.45 a.m., Nov. 25.
Nov. 25,	8.45 A.M.	Blast put on ; blast volume, 15,000 cub. ft. per minute. Nos. 2, 4, 6, 8 and 10 tuyeres closed.
	10.30 A.M.	Pipe withdrawn from tap-hole.
	11.30 A.M.	Blast increased to 20,000 cub. ft. and gas into the holder.
	3.30 P.M.	Opened Nos. 6 and 10 tuyeres and increased blast to 25,000 cub. ft. Furnace working freely and looking hot.
	8.15 P.M.	First slag. Hot and grey.
	8.30 P.M.	Blast increased to 28,000 cub. ft. 1,000 lb. Thaba ore and 200 lb. dolomite added per round.
Nov. 26,	2.20 A.M.	No. 2 tuyere opened. Foreman's report says "Slag grey and hot. Impossible to be better."
	3.00 A.M.	Last flush of slag. 2¾ ladles over notch. Furnace tapped. One ladle metal, 1½ ladles roughing slag. Iron very grey.
	7.00 A.M.	1,000 lb. Thaba and 200 lb. dolomite added per round. Nos. 4 and 8 tuyeres opened and blast increased to 30,000 cub. ft. All tuyeres now open.
	10.15 A.M.	Second cast. Iron hot and slag fluid. Burden increased by 1,000 lb. Thaba ore and 300 lb. dolomite per round.
	2.40 P.M.	Third cast. Good metal. Furnace driving freely.
	6.50 P.M.	Fourth cast. Good metal. Furnace driving freely.

Hanging and Slipping are very rare occurrences when working to the method described. Hanging usually begins because of the furnace running too hot or too cold. The appearances of the crude gas, the tuyeres and the slag at once indicate in which direction the furnace is swinging, and suitable adjustment of the blast temperature, with gentle checking of the furnace, will overcome it in the early stages. If possible, the furnace is allowed to slip on its own by adjustment of the blast temperature, but if checking is necessary, it is accomplished by signalling the blowers to ease down, with the snort-valve shut. This ensures a cushion of blast to prevent the burden from slipping heavily into the converging lines of the bosh and jamming tightly, so that the gas cannot penetrate the coke and slag in the bosh. This condition is recognised by the difficulty of forcing a bar through the tuyeres. A further danger in the sudden slipping of the furnace is the possible loss of tuyeres due to slag or metal being forced up to them.

Incorrect tuyere size for the particular furnace and volume of air blown will also cause irregular working, due to pillars either between the adjoining tuyeres or in the centre of the furnace. Tuyeres of different length or diameter will correct this, but, consistent with regular working, tuyeres should be as short as possible. To illustrate this, Iscor No. 1 furnace worked throughout 1938 and 1939 with 12 in. by 5 in. tuyeres of standard design, and the average life per tuyere was 429 days. During the same two years, No. 2 furnace, working on the same burden and grade of metal, with 15 in. by 5¼ in. tuyeres, had an average tuyere life of 203 days. Both furnaces worked freely and well, and there were no signs of pillars or scaffolds. Both sizes of tuyeres were of the same general design and supplied by the same maker. The water strainers at the furnaces are changed over and cleaned regularly, and the individual cocks for the cooling members are of the three-way type, so that they can be flushed regularly.

Care of Tap-Hole, Ladles, etc.—At Iscor, Brosius electric clay guns are used and the tap-hole is stopped against pressure. The local clays are highly aluminous with consequent heavy shrinkage, so that a proportion of the shale is calcined in the dolomite kilns before use. The tap-hole is kept well back inside the collar and is drilled with a rotary air drill with a 2-in. bit. The tapping trough is made up to a constant level each time by the use of a gauge and the hole is drilled regularly at the same angle. The skimmer is made up of 13½-in. firebricks held in a channel-iron frame, while the dam consists of four 9-in. firebricks, two on edge 3 in. apart in the runner, and two on the flat laid over them, giving a hole 3 in. square. This aperture is filled with hot sand and the whole of the dam is rammed over with loam, which is also used in the runners, and dried with blast-furnace gas. The levels of the dam and skimmer are arranged so that the gun nozzle does not go through the metal when entering the tap-hole.

The hot-metal ladles are of the enclosed type and hold 60 short tons. They have a course of insulating brick next to the shell and two courses of firebrick. It is customary to get about 300 to 350 casts, after which the inner course is renewed. With this type of ladle it is necessary to clean up the throat each time they come back from the melting-shop or casting-machine, especially if there has been much delay in pouring. Occasionally it is necessary to burn accumulations off the lip using oxygen. Slag ladles are simply grouted with clay-wash. Originally cast-iron pots were used, but were later replaced by steel pots, which gives about four times the life.

Pig-Casting Machine.—This item of the plant gives little trouble, provided that ample water is available and all sprays are kept in good repair. Those on the conveyor rails at the pouring spouts and on the shot plates are kept going to prevent metal from building up, and a labourer is stationed at the latter point to rake away the shot as it is formed. Careful pouring and attention to the lime-sprays are essential to keep scrap down to a minimum. It has been found very helpful to place 30-lb. rails, spaced so that the lime-sprays can still reach the moulds, over the lime-vat and below the moulds as they return in the inverted position. This prevents pigs stuck in the moulds from falling on to the lime-sprays or tank. Especially when casting basic metal, it is necessary to have a man with a chisel bar near the top of the strand to ease up the pigs before they reach the discharge chute.

Personnel.—It has been necessary in South Africa, as in other new countries, to train local men, including natives, for blast-furnace work. Originally three foremen were brought out from England, and they have been responsible, under the manager, for the training of local labour with which both plants are staffed. The proportion of natives to Europeans is about 3 to 1, and on the furnaces themselves the only European is the keeper. The local labour has adapted itself remarkably well to blast-furnace conditions, especially as the climate is rather hot. Protective clothing in the way of goggles, gaiters of canvas impregnated with alum, and asbestos coats and gauntlets, are provided for natives about the furnace and pig-casting machine, as their usual clothes are often of the sketchiest kind. All Europeans are trained in the use of gas masks and are subject to half-yearly examination and training. First-aid training is also provided. A large, airy change-house is available, and is more or less a necessity in this climate. The usual three eight-hour shifts are worked, but on the average only 48 hours per week. Relief men are used and their duties arranged so that each man has a long week-end off every third week. All workmen have three weeks' paid leave per annum and a holiday bonus, based on actual earnings.

Both in the Transvaal and in Natal the bulk of rainfall occurs in the summer months—October to March—and mostly in the way of heavy thunderstorms. On occasion, 4 in. or 5 in. of rain may fall in as many hours. It is necessary therefore to provide ample storm-water drains and to see that these are kept open. All low points, such as stock-house, skip-pits and weighbridge sumps, which cannot be drained into these sewers, must have pumps or other apparatus installed. During these periods of heavy precipitation the furnace burdens must be adjusted to allow for absorbed moisture, which is often very heavy.

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AUTOMOBILE RESEARCH.

Although present conditions have in no way modified the value of research in the engineering field, they have naturally at times tended to alter its direction. For instance, at the outbreak of war, the Automobile Research Committee of the Institution of Automobile Engineers was carrying out an investigation on brake squeak. This matter, although of interest to motorists, is clearly of minor importance under war conditions, and the investigation has consequently been abandoned. The same thing applies to tests on temperature-sensitive paints. A research on motor-cycle silencing has also been discontinued, the reason in this case being that the British Cycle and Motor Cycle Manufacturers and Traders' Union, which had contributed generously to the work, found itself unable to continue its support. In contrast with these examples, many of the researches in progress have become of additional importance, and work on such matters as creosote as a fuel for compression-ignition engines, aeration and frothing of lubricants, and power deficiency with gas-producer operation has been carried on with energy. The laboratories have also been faced with a considerable increase in the number of private investigations called for. These have concerned such matters as cold starting, new bearing materials, anti-freeze mixtures, and aero-engine crankshafts. This work has naturally been mainly of a confidential nature and no detailed information will be published.

The Ninth Annual Report of the Committee, which has just appeared and which covers the year July 1, 1939, to June 30, 1940, states that at the outbreak of war a series of summary reports was prepared. These reports, which dealt with all researches in progress, were circulated to all affiliated members of the organisation who were asked to indicate which particular researches should, in their opinion, be carried on and which abandoned. In this way an order of priority was determined which was best calculated to assist the industry in its war activities. This procedure also produced suggestions for work on other war-time problems, the most important of these relating to alternative home-produced fuels. A second inquiry of the same type was made last June, in order to keep the activities of the Committee closely in touch with any special problems which the present condition of affairs might have raised. The extensive nature of the work being carried out by the Committee is indicated by the list of 30 research reports which have been issued during the year under review.

At the first meeting of the Committee following the annual general meeting in July, 1939, Mr. W. A. Tookey and Mr. G. H. Lanchester were re-elected chairman and vice-chairman, respectively. The report, however, has to record an important change in the staff of the organisation, Mr. C. G. Williams, the director, having retired on September 30 last, after seventeen years service. His successor is Dr. E. Giffen, formerly of King's College, London. Dr. Giffen's work in connection with internal-combustion engine research over many years, will be well known to our readers. The membership of the Committee has not suffered owing to war conditions. The number of affiliated manufacturers and operators at June 30, 1940, which amounted to 305, was the same as at June 30, 1939, nine resignations having been balanced by nine new members. The finances of the Committee are also in a fairly satisfactory state, although, as with many other research associations, it has not been found possible to qualify for the full grant offered by the Department of Scientific and Industrial Research. The Department promised a contribution of 6,000*l.* a year on condition that 12,000*l.* was raised by the industry. It was at one time expected that this figure would be reached, but soon after the outbreak of war the Society of Motor Manufacturers and Traders intimated that, owing to its principal source of income having ceased as a result of the impossibility of holding the Motor Exhibition, it would be unable to make its usual grant of 2,500*l.* a year. A payment of 625*l.* was, however, made for the quarter ending September 29, 1939. In view of the special conditions, the Department of Scientific and Industrial Research waived its original condition and promised to contribute 1*l.* for every 2*l.* raised by the industry. Several other subscribers have increased their contributions and the affiliated members have subscribed their usual amounts, with the result that the subscription income exceeded that of any previous year. The total grant-earning income raised was 10,186*l.*, so that a sum of 5,093*l.* was provided by the Department. The excess of expenditure over income for the year was 807*l.*, as compared with 846*l.* for the previous twelve months.

The Committee has been able to continue its useful work in the preparation of abstracts, and within a month of the outbreak of war was able to issue a collection of such abstracts dealing with producer gas and compressed gas for motor vehicles. This was followed, in November, 1939, by a further collection dealing with home-produced liquid fuels for road vehicles. Collections on fatigue of metals and bearings has since been issued. In connection with the abstracting and information service, it is of interest to note that the Information Department has been able to obtain supplies of German and other technical publications through neutral sources. This is obviously of considerable value to many members, the majority of whom will have found their supplies of most foreign technical journals entirely cut off.

SYNTHETIC RUBBERS.*

By Lawrence A. Wood.

Synthetic rubber has been the dream of many during the century which has passed since Faraday first determined the carbon-hydrogen ratio in natural rubber, but it has completed only about a decade of commercial success. Every year of the past ten has seen an increase in the quantity produced, the number of varieties available, and the number of applications. The aims in various countries have been different and the development has proceeded in different directions. The most active research has been carried on in Germany, Russia, and the United States. There has been relatively little collection and intercomparison of the rather limited data on the physical properties of the different varieties of synthetic rubber. Because of the relatively short time during which the different varieties of synthetic rubber have been available, the data concerning them have been reported almost entirely by observers in the laboratories of companies each interested in the manufacture and sale of a particular variety. In almost every case, therefore, the figures necessarily lack independent confirmation.

The development of synthetic materials to replace those of vegetable or animal origin has been a matter of frequent occurrence. Many examples can be cited, beginning with alizarin and indigo and continuing with dyes, fertilisers, drugs, and vitamins. Usually, the development follows a fairly well-defined pattern, consisting of (1) scientific research on the analysis of the natural product leading to an exact knowledge of the chemical constitution and structure; (2) the evolution of methods for the duplication of the substance from cheap raw materials; and (3) the commercial production of the synthetic product at a price low enough to compete with and even to displace the natural product. In most cases, the synthetic product is chemically and physically the same as the natural product and is not an improvement, unless the absence of impurities or non-essential ingredients can be considered an improvement. Although thirty years ago the expectation was general that the development of synthetic rubber would follow this course, it has not done so, since serious difficulties were encountered with each of the three steps of the typical pattern of development. Consequently, scientific workers engaged in much research which now seems fruitless.

Scientific research on natural rubber has yielded much information, but even to-day it cannot be said that the structure of rubber is known in the sense that the structures of most substances of lower molecular weight are known. Our knowledge, though incomplete, is probably sufficient to enable us to say that no process has yet been found by which it is possible to produce a material possessing both the chemical constitution and the physical properties of natural rubber. Finally, the cost of the synthetic products which most nearly approach natural rubber in character is far above the present price of natural rubber. It seems now to be recognised that the desirable physical properties of rubber are not necessarily closely related to its chemical constitution, and since, in almost all its uses, its physical properties are of first importance, the effort to duplicate the chemical constitution of natural rubber has been abandoned.

In recent years, the very meaning of the term "synthetic rubber" seems to have changed to agree with the change in the point of view. Thirty years ago, the term meant a synthetic material physically and chemically indistinguishable from natural rubber, except possibly for the absence of impurities. Since no material has been produced which fits this definition, the term has come to mean, to most people, a synthetic material possessing the approximate physical properties of natural rubber. Several authors have attempted to express such a definition in more exact terms. Others, following the older definition, have hesitated to use the phrase "synthetic rubber" and have taken refuge in the more indirect expressions "synthetic rubberlike material," "elastic synthetic," and "rubber substitute." Perhaps the most satisfactory solution would be the adoption of some single word such as "elastomer," as suggested by H. L. Fisher, but as yet no such word has met with general acceptance. The term "synthetic rubber" has been used so widely that it would probably be difficult to displace it.

The economic factors involved in the production of synthetic rubber have changed considerably in the past 30 years. The cheapest commercial synthetic rubber still costs about twice as much as the natural product. Nevertheless, in recent years, certain countries, notably Germany and Russia, insisting upon economic self-sufficiency, have considered a high price paid within the country to be of little importance as compared with expenditure in foreign currency for natural rubber. Self-sufficiency in war-time, of course, has also been a factor of paramount interest to these governments.

These economic and political factors have influenced the scientific objectives and development in the different countries. In Germany and Russia, the primary aim appears to have been to duplicate, or nearly duplicate, the properties of natural rubber as cheaply as possible and any improvement in qualities seems to have been of only incidental or secondary importance. In the

TABLE I.—Varieties of Synthetic Rubber.

Name.	Type.	Remarks.	Manufacturer.	Country of Origin.
Buna 85	Butadiene polymer	Molecular weight about 85,000	I.G. Farbenindustrie	Germany
Buna 115	" "	Molecular weight about 115,000	" "	"
Buna N*	Butadiene co-polymer	Co-polymer with acrylonitrile; now called Perbunan	" "	"
Buna S	" "	Co-polymer with styrene	" "	"
Buna SS	" "	Co-polymer with styrene—higher styrene content than Buna S	" "	"
Duprene*	Chloroprene polymer	Now called Neoprene	E. I. duPont de Nemours and Company, Inc.	United States
Ethanite	Organic polysulphide	Similar to Thiokol A	Belgian Cracking Company	Belgium
Flamenol	Plasticised vinyl chloride polymer	—	General Electric Company	United States
Ker	Butadiene polymer	—	Stomil Company	Poland
Korogel	Plasticised vinyl chloride polymer	Highly plasticised Koroseal	B. F. Goodrich Company	United States
Koroseal	" "	—	" "	"
Levulkan*	Butadiene co-polymer	Now called Buna SS	I.G. Farbenindustrie	Germany
Methyl rubber B	Dimethylbutadiene polymer	Sodium used as catalyst	Bayer and Company, 1915-18	"
Methyl rubber H	" "	Cold polymerisation	" "	"
Methyl rubber W	" "	Hot polymerisation	" "	"
Neoprene	Chloroprene polymer	—	E. I. duPont de Nemours and Company, Inc.	United States
Mustone	" "	—	Umeno Institute	Japan
Oppanol	Isobutene polymer	—	I.G. Farbenindustrie	Germany
Perbunan	Butadiene co-polymer	Co-polymer with acrylonitrile	" "	"
Perbunan Extra	" "	Co-polymer with acrylonitrile—higher nitrile content than Perbunan	" "	"
Perduren	Organic polysulphide	—	" "	"
Resinit*	" "	—	—	Russia
SKA	Butadiene polymer	From petroleum	—	"
SKB	" "	From alcohol	—	"
Sovprene	Chloroprene polymer	—	—	"
Thiokol	Organic polysulphide	—	Thiokol Corporation	United States
Thionite	" "	—	—	Japan
Vistanex	Isobutene polymer	—	Standard Oil Company	United States
Vulcaplas	Organic polysulphide	—	Imperial Chemical Industries	England

* This term is now commercially obsolete.

* *Synthetic Rubbers: A Review of Their Compositions, Properties and Uses.* Circula. C 427 of the United States National Bureau of Standards. Washington, D.C.: The Superintendent of Documents. [Price 10 cents.] Abridged.

United States, on the contrary, the primary aim has been to produce a product superior to natural rubber in some respect, the cost being a matter of secondary importance. In a free world market, only a superior synthetic rubber can justify a higher price. Whether or not in the future the other countries, including the United States, will be moved by considerations of self-sufficiency to follow Germany and Russia remains to be seen. Up to the present time, such considerations have not played much part in the development of synthetic rubber in these countries.

In conformity with the trend already mentioned, the term "synthetic rubber" in this paper will be taken to mean merely a synthetic substance which has physical properties resembling those of natural rubber; that is, it can be stretched a considerable amount, say, to an elongation of at least 300 per cent., and when released will quickly and forciby retract to substantially its original dimensions. About 30 varieties of synthetic rubber are listed in Table I, opposite, under the trade names used by the manufacturers. Of these, some are practically identical and some are very closely related to others. They have been classified in six general types according to chemical composition; the discussion in the present paper follows this classification. The chemical constitution of almost all of the varieties in Table I, together with that of natural rubber, is shown in Table II, on this page.

In common with natural rubber, all types of synthetic rubber consist of atomic chains of very great length—giant molecules, as they are sometimes called—built up by the repetition, usually thousands of times, of some unit configuration. In all but the last two cases shown in Table II, the long chains are built up by the polymerisation, or linking together, of the molecules of liquids. In the process of formation of the polymer from the liquid monomer, in each case the double bond attached to a carbon atom at the end of the molecule opens to form the necessary valence bond for attachment to the next unit. The organic polysulphide rubbers, which are illustrated by the last two types in Table II, possess long chains formed not by polymerisation, but by condensation. The atoms at the ends of two different molecules combine with each other, thus leaving the remaining radicals free to combine, and forming long chains by the repetition of the process. In none of the different varieties of synthetic rubber has the nature of the terminal group of the chain been definitely established. It comprises only a very small fraction of the total material and may be different in different chains of the same material.

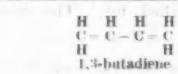
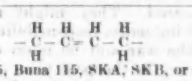
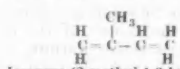
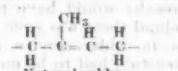
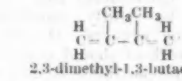
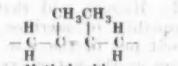
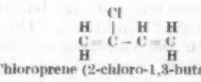
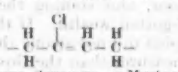
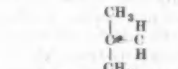
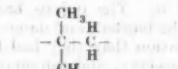
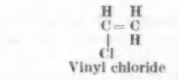
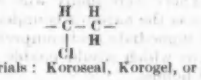
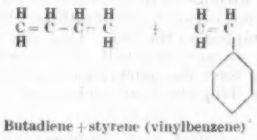
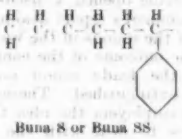
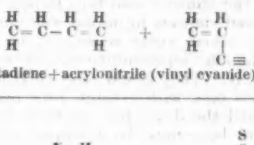
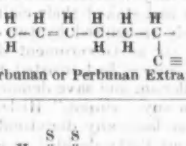
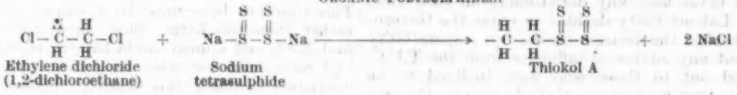
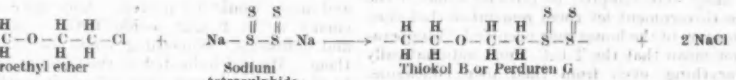
The production of synthetic rubbers involves two steps—the manufacture of the monomer, and the polymerisation or condensation reaction. The first step usually follows fairly common and well-understood reactions; the second step is much more empirical and less understood, but usually involves the use of a catalyst and the control of temperature and pressure. One of the most important improvements during the past few years has been the adoption, in many cases, of polymerisation in emulsion. The monomer is emulsified in a liquid, usually water, and the product is a suspension similar to the latex of natural rubber. Another important advance was the discovery and development of co-polymerisation. This is a process involving the simultaneous polymerisation of two or more liquids and yielding a product in which a single chain contains units of both configurations. The co-polymers of butadiene with styrene and of butadiene with acrylonitrile are the best-known examples.

Prolonged research has failed to locate a cheap source of supply for the manufacture of isoprene, or to produce from it a polymer with physical properties close to those of natural rubber. Consequently, efforts in these directions have been almost completely abandoned, and all the commercial synthetic rubbers differ chemically from natural rubber. Between 1915 and 1918, the Bayer plant in Germany produced about 2,500 tons of rubber from dimethylbutadiene. The product, called "methyl rubber," has not, since then, retained any commercial importance. With these exceptions, and possibly a few others, all the materials shown in Tables I and II are at present in commercial production, although some are produced in very limited quantities. From the diversity of chemical constitutions shown by the examples in Table II, one may conclude that the physical properties ordinarily associated with rubber are not limited to one group of related chemical compounds and that there are probably many more undiscovered types of synthetic rubber.

(To be continued.)

TABLE II.—CHEMICAL STRUCTURES OF DIFFERENT VARIETIES OF SYNTHETIC RUBBER.

NOTES.—The bonds between carbon and hydrogen are not indicated. The structural formulæ are not intended to give any indications regarding stereo-isomerism. C. S. Fuller has recently suggested a ring structure in the organic polysulphides.

Monomer.	Unit of Polymer.
SIMPLE POLYMERS.	
 1,3-butadiene	 Buna 85, Buna 115, SKA, SKB, or Ker
 Isoprene (2-methyl-1,3-butadiene)	 Natural rubber
 2,3-dimethyl-1,3-butadiene	 Methyl rubber
 Chloroprene (2-chloro-1,3-butadiene)	 Neoprene, Sovprene, or Mustone
 Isobutene (2-methyl-1-propene)	 Vistanex, Oppanol
 Vinyl chloride	 Plasticised materials: Koroseal, Korogel, or Flamenol
CO-POLYMERS.	
 Butadiene + styrene (vinylbenzene)	 Buna S or Buna SS
 Butadiene + acrylonitrile (vinyl cyanide)	 Perbunan or Perbunan Extra
ORGANIC POLYSULPHIDES.	
 Ethylene dichloride (1,2-dichloroethane); Sodium tetrasulphide; Thiokol A; 2 NaCl	
 Dichloroethyl ether; Sodium tetrasulphide; Thiokol B or Perduren G; 2 NaCl	

LEADERSHIP AND DIRECTION IN INDUSTRY.*

By WILFRID AYRE.

WHATEVER value we may have attached in the past to the attributes of leadership and direction in industry, the course of the present war to date has proved unmistakably that these qualities are now of the first importance. When total war comes, necessity demands production on an unprecedented scale with an increased rate of output. It is then not unusual to find either that manufacturing methods acceptable for a peace-time standard of output are totally inadequate for war-time emergency, or that there is insufficient flexibility to permit the adoption of a rate of production far beyond the normal capacity of the works. In such conditions, leadership in industry must be entrusted with the task of stimulating imagination, applying foresight, exhibiting genius and imparting vigorous action in solving the new problems created.

Organisation and leadership are the nerve centres of industry; competition in peace time, their activating force. Without them no industry can survive. Competition can never be eliminated from commerce except in an Utopian world, and efficiency of organisation—coupled with enterprise—will always favourably decide the competitive issue. Leadership is a virtue of industry and the real driving force behind all organisation; it demands the energy, will and enthusiasm to develop every material resource, actual and potential, of which any unit of industry may be possessed. An inert or tradition-bound attitude towards the day-to-day problems of organisation, production, finance or salesmanship, can never command the maximum economic result, nor hope to raise the status of executive or administrative authority to the highest level. Indeed, war-time experience has proved in innumerable instances that peace-time standards and practices of industrial management, direction, leadership and outlook completely fail to drive the machinery of production at that overload speed and capacity which emergency conditions demand. Leadership must lead, and, through its manifold responsibilities, direct organisation to production.

The selling value of any product has its roots in those technical considerations which are concerned with quality of design, cost of manufacture, and, ultimately, performance. So far as the production problem is concerned in its relation to cost of manufacture, this must be indissolubly allied with organisation and efficiency. Herein lies one of the biggest and most urgent problems of industry. In the spheres of commerce, finance and salesmanship, innumerable issues arise, which call for such action as is prescribed by the broad lessons of experience, however dearly bought these may be. Opinions may differ widely with regard to the degree of technical knowledge considered essential in the individual for success in the field of production. But experience proves that expert technical knowledge of the product of any manufacturing industry is of the greatest importance, particularly in its relation to degree of performance, cost of manufacture and saleability.

The value of a technical standard of ship or marine-engine design, for instance, has been well demonstrated

* Presidential address to the Institution of Engineers and Shipbuilders in Scotland: delivered in Glasgow on Tuesday, October 15, 1940. Abridged.

during the past ten years. Let us admit, quite frankly, that for too long a time, before the year 1930, the design of cargo ships reposed in a state of quiescence yielding to a placid and unintelligent policy of repetition, devoid of technical character and lacking in commercial performance when compared with the pace of scientific progress in other directions, and unworthy of the two industries responsible for their creation. Such a condition did not apply exclusively to our own industry; it prevailed—perhaps to a lesser degree—in shipbuilding countries throughout the world. The quickening rate of technical progress in aviation, constructional engineering, motor-car design, and developments in internal-combustion engines made it plain, however, that, if shipping services were to be operated by ships possessed of that standard of efficiency so essential for dealing with the quickly-changing conditions of world maritime trade, ship design, in its widest sense, demanded drastic and immediate improvement. The writing on the wall was there for all to see, and fortunately was not missed, for there was initiated at that time a far-reaching drive towards research into the possibilities of greatly improving the standard of performance, particularly of cargo ships. This subject has continued to dominate the interest of shipowners ever since.

When executiveship fails to do so, then leadership must initiate technical progress, if only because the duties and responsibilities which belong to it bring more opportunities of becoming aware of the potentialities and requirements of industrial production than perhaps any other in an industrial organisation. Technical progress in ship design, for example, is moving swiftly towards optimum efficiency. The records of scientific research in ship-propulsion problems, published in many countries, demand insistently an intimate knowledge on the part of every live shipbuilding organisation. Electric welding is fast displacing riveted connections in ship construction and moulded castings in engineering assembly. Here we have a comparatively new development full of possibilities and problems for executives responsible for planned economic production, a development which, indeed, threatens to alter the face of shipbuilding and engineering practice. Power plants for ships range from coal- and/or oil-fired boilers, driving engines embodying various arrangements of superheated steam, to Diesel engines of great diversity in design, if differing but little in performance. A technical knowledge, if only of a superficial nature, of the characteristics and potentialities of each of these modes of ship propulsion, coupled with a watch on their subsequent development and progress, is an essential requirement of leadership in shipbuilding and engineering.

At no time is technical knowledge of greater value than when business negotiations are actively in progress. The ability to discuss, and dispose of on the spot, any technical problems that may arise, rather than to "refer it back to the works," often outwits competition and results in a speedy and fruitful conclusion of business negotiations. In the absence of this attribute, delay is occasioned, the alternative to which is the untimely and often inconvenient presence of technicians frequently as unaccustomed to, as they are inexperienced in, the practical art of salesmanship. In shipbuilding, its importance cannot be over-rated. Few industries find it more difficult than shipbuilding to pursue to the full the principles of organisation and co-ordination. Shipbuilding processes are far removed from mass-production methods, while the variety of trade categories, restrictive measures in the labour situation, and in time and piece-work systems of payments, oppose the prosecution of many desirable principles of industrial management that have been found profitable—and positively essential—in other industries. These restrictive influences need not, however, prevent shipbuilding methods from being analytically examined, planned and co-ordinated to give the best possible efficiency. The conception of production in any works should visualise an uninterrupted flow of output where the factory as a whole operates at the same degree of efficiency as any individual process that is subjected to modern principles of planning; where management and foremen are output-minded and possess exact knowledge of the volume of output of which the plant is capable and the "target" output aimed at; and where labour is infected with creative enthusiasm rather than disinterested complacency.

(*To be continued.*)

The Late Mr. G. B. Richards.—We note with regret the recent death, as the result of a motor-car accident, of Mr. George B. Richards. Mr. Richards, who was 43 years of age, joined Messrs. Higgs Motors, Limited, Witton, Birmingham, 6, in 1926, and for the past three years had held the office of sales director. During the war of 1914-18, he served in the Royal Engineers.

LABOUR NOTES.

Addressing the Trades Union Congress, which met at Southport last week, Mr. William Holmes, the president, said that the past year's work had been one of real statesmanship. New relationships had been developed with the Government, individual Ministries, public departments, and employers' organisations, and if at times decisions on policy were taken in great haste and urgency, no vital trade union interest was surrendered or compromised. On the contrary, the General Council had secured, for trade union principles, a fuller recognition, a wider application, and a more generous understanding. Old industrial and political antagonisms arising from prejudice and misunderstanding and class hostility had lost their force, if they had not entirely disappeared. They might revive, but the movement's new influence, responsibility, and authority would survive the war and be more widely extended afterwards. Policy in the past year was to be judged therefore by its long term aim as well as by immediate results. Those results would have permanent value, but the policy behind them was even more significant, and would show in wider service when peace-time economic reconstruction had to be undertaken.

Continuing, Mr. Holmes said that the movement must demand equality of sacrifice, and that none should make profit out of the war. Profiteering in such circumstances as the nation was called upon to face was as dastardly a crime as looting the shattered homes of the poor, and coining the miseries of the homeless into ill-gotten wealth. If the manifestations of the people's spirit did not shame the greedy and the selfish, sterner measures than the Government had yet applied must restrain them and make it impossible for anybody to slink away at the end of this war richer than he entered it. The unions had redeemed their pledge to share the burdens and dangers of the struggle. No further revelation than they had had of the malignant cruelty, treachery, and inhumanity of the forces arrayed against them could do more then strengthen their resolve. It could not terrorise them or make them flinch. There were many who had lost all they possessed. It was the nation's bounden duty to recompense them by immediate and comprehensive measures of compensation which would enable them to restore their shattered homes.

Sir Walter Citrine opened a discussion on the part of the General Council's report dealing with the policy and activities of the unions in the war. They realised, he said, that the outcome of the conflict would determine whether the trade union movement was to continue or be extinguished. There had been in the minds of some employers the idea that trade unions had no business to deal with the wider sphere of questions which they described as managerial functions. But the unions had staked their claim for recognition and had it freely recognised by two successive Prime Ministers. As far as Government departments were concerned, the unions had insisted that in this fight to suppress Hitlerism and save democracy there should not be built up any "tinpot" Hitlers in their midst. There had never been any dictatorship on their side. When the Labour Party decided to enter the Government, it reached the decision on its own responsibility and without any advice or influence from the T.U.C. He pointed out to those who were inclined to be critical that they were in a period of coalition Government. If they were tempted to criticise some of the men in the Government let them remember that they were not masters of the house they occupied. Co-operation did not mean that the T.U.C. must automatically accept everything, even from their own colleagues. He ridiculed the suggestion that because they had men in the Government the trade union movement was bound hand and foot to any policy that the Government might adopt.

A Birmingham representative of the Amalgamated Engineering Union declared that the workpeople did not object to working during air raids. Those in the workshops who had reached the age of discretion were as patriotic and willing to provide the tools to beat Hitler as those outside, but they wanted a sporting chance of protection. A joint memorandum on working after the sirens had never been properly applied. Factory shelters should be at least "get-at-able." In the course of a reply to this delegate, Sir Walter Citrine said that there was the danger at first that a single raider, without dropping bombs, might cause loss of production. If Hitler could succeed in slowing down production, he achieved his aim. If he could get people into shelters when it was not necessary for them to take shelter, then he succeeded in preventing the building of an adequate defence. It became a practical question of what could be done consistent with protecting the workman to maintain production during air raids. No system of warning or "spotters" could guarantee complete safety for anybody. Every step had been taken for the workmen to be consulted. Arrangements were being made with the Ministry of Labour to hold local conferences at large works at which employers, workmen, and the R.A.F. would be represented and the air-raid warning system fully explained.

An emergency resolution moved on behalf of the General Council emphasised the determination of the unions to continue the war, approved measures to safeguard their interests, and called for a fuller recognition of their place in the social and economic life. Homage was paid to the bravery of all engaged in service and civilian defence, sympathy was expressed with the victims of air raids, and adequate care for the homeless was called for. The resolution was carried.

A paragraph in the General Council's report gave the agreed conditions under which work was to be continued after the public sirens had sounded. Among the points urged in the course of the discussion on it were deep shelters, a better warning system, more time to make plant safe and adequate compensation. Dealing with the various suggestions, Sir Walter Citrine said that the Government had stipulated that precautions should be jointly considered by the managements and the workers. If this instruction were not observed workers should complain to their unions. If all workpeople liable to risk were to be provided with deep shelters we should be digging for 10 years. Risks were unavoidable, but they should be taken under specified conditions. They had been in consultation with the Government, which agreed that the whole country was a danger area, and no distinction was to be made, in allowances for safety measures, between employers in specified and unspecified areas. The council had applied to the Ministry for increased supplies of the articles necessary for air-raid protection. As to compensation, there must be a legal right under the civil-injuries scheme. The Congress approved the paragraph.

Mr. Bevin, the Minister of Labour and National Service, addressed the Congress at its concluding session. In reply to those in "bombed districts" who cried "Bomb the enemy," he said: "We will do that." "An eye for an eye, if you like," he declared, "but to do it we must have the bombs and the bombers, greater carrying capacity, the Spitfires, the guns and the Navy equipped to the full. That will not destroy so much life as weakness will. The quicker we get overwhelming force the quicker will the Nazis cry off. It is the only thing the Nazis understand."

Proceeding to deal with problems of immediate importance, the Minister said that though he invented the idea of roof spotters he would welcome any better scheme. He asked works managers, in conjunction with trade-union representatives, to examine the problem closely. They would reply to Hitler with two bombs for his one, with greater force every time he attacked, until the day when we took the initiative. This time our boys must be equipped with too much rather than too little. More man-power had to be mobilised, and women would have to be called on more and more, and for other industries. That raised an enormous problem this winter. Thousands of men and women had been moved from their domestic circle, and more would be moved. And there was another enemy to be fought beside Hitler—epidemics, cold, and influenza. Something could be done to check them. He had indicated to the Cabinet that he would have to make canteens compulsory in works employing more than a certain number. That would come before the Factory Welfare Board at its next meeting.

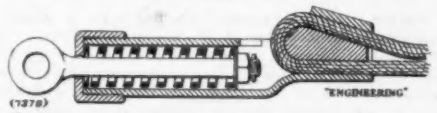
Then, Mr. Bevin said, there were the women and young people leaving the factories in the morning in the winter-time with perhaps an hour's 'bus or train ride before them. He regarded the provision of hot refreshment before they started that journey as vital. Trade unionists could help to do that. If bombing continued on an extensive scale they would have to consider the extension of communal feeding inside as well as outside the works, because home cooking arrangements might suffer with gas and electricity failures. More and more married women would be called upon, and he was pressing for the rapid extension of properly equipped day nurseries for the children.

A composite resolution, which was adopted unanimously, declared that the trade unions could best help the war effort if they were free to function in their own way, and specifically urged the removal of "unfair and unjustifiable restrictions," imposed by the Trade Disputes and Trade Unions Act of 1927.

SHOCK-ABSORBING COUPLING FOR EXCAVATING PLANT.

ANYONE who has watched a dragline excavator or similar machine at work can hardly have failed to notice the continual succession of small shocks in the wire-rope connections due to the action of the machine itself, in addition to the heavy shocks arising from the digging and lifting movements. The normal connections of the dragline excavator hold the rope in a rigid grip, but, with the object of minimising breakages, Messrs. Brown Lenox and Company (London), Limited, Millwall, London, E.14, manufacture the device shown in the accompanying illustration and known as Turner's Patent Shock-Absorbing Socket. The construction of the socket scarcely calls for comment, as it will be evident that shock on the rope is absorbed by a compression spring between its end and the point of attachment. The rope is held in the socket by self-wedging action.

Messrs. Brown Lenox claim that the socket not only prolongs the life of the rope by ten times to twelve times but also effects a saving in the quantity of rope used since, with the ordinary socket, when a rope has broken at the fastening several times the rest of the rope, generally in good condition, has to be discarded as it is too short for further use. With the new device the breakages are stated to be so infrequent that the whole of the rope has been utilised by the time it must be discarded. Apart from the saving in rope itself, the time saved by the reduction of



stoppages for repair increases the output of the machine concerned. Some actual records of performance may, through the courtesy of Messrs. John Mowlem and Company, Limited, London, be cited here. The new socket, as applied to the tip rope of three dragline excavators all working on double shifts, gave very satisfactory results. One of the excavators was a 1-cub. yd. steam-driven machine and the life of the rope before fitting the new socket was 7 days to 8 days. After fitting the socket the rope lasted for 6½ weeks. The other two excavators were 1½-cub. yd. Diesel-engine driven machines, the rope lasting from 2 days to 3 days. The new socket gave a rope life in one case of 3 weeks and in the other of 4 weeks. Equally good results were secured on a ½-cub. yd. Diesel-engined navvy. Before the new socket was fitted the rope lasted for 7 days, but with the socket the life was increased to 11 weeks. This machine worked on a single shift. The Turner socket is made in three sizes, for use with ½-in., ¾-in., and ⅞-in. rope, respectively.

THE EVOLUTION OF THE SUGAR-CANE MILL.*

By NOEL DEERR, F.C.G.I., and ALEXANDER BROOKS, A.M.I.Mech.E.

IT has been definitely established that the habitat of the sugar cane is in the South Pacific, whence at some remote period it travelled, by way of the bridge of islands linking south-eastern Asia to Australia, to Indo-China and to India. The first definite mention of sugar is that of Nearchus, a general of Alexander the Great, who in 325 B.C. in western India met with "honey not made by bees." From India the cane travelled to Persia, arriving there in the Euphrates-Tigris delta about 500 A.D., whence, in the Seventh Century, Arab expansion carried it throughout the littoral and islands of the Mediterranean. What sugar reached western Europe came from this area till 1425, when Dom Henry the Navigator caused the cane to be taken to Madeira. This was soon followed by extensions to the Canaries, the Cape Verde Islands, and to the equatorial island of Sao Thome, in all of which, especially the last named, a lucrative industry developed. To the New World the cane was taken by Columbus in his second voyage, but it was not till 1516 that the industry became established there, when Miguel Balestro and the brothers Christoval and Francisco Tapia built near the Rio Nizao, in Hispaniola, the first "ingenio."

It is in India that the first records are found of mechanical means being used for the expression of the juice for use in the separation of sugar. The first reference appears in Buddhistic writings, of date earlier than 100 A.D., and runs:—"As a sugar cane stalk is thrown to the ground to be dried for burning after all the juice has been extracted by pressing in the mill, so the body pressed in the mill of old age awaits the funeral pyre." We are inclined to believe that reference is made here to the pestle and mortar, one of the oldest, if not, indeed, the oldest, appliance used for the expression of liquids, especially oils. For this purpose many thousands are still in use in India.

The earliest description of appliances used to express the juice of the cane refer to practice in the Mediterranean area. A very short notice from Jacobus de Vitriaco in the Thirteenth Century runs:—"There are also reeds full of a very sweet juice from which, after compression by means of a screw and concentration by fire, sugar is obtained." A much fuller account of the same period is that given by Al Nuwari in his *Encyclopædia*, and which, referring to Egypt, reads:—"A man takes a number of stalks and cuts them into small pieces, which he throws into the 'house of the pouring.' They are then placed in baskets called Ijjara, which are all of the same size. They are then carried to the mill stone. The cane is laid under the stone which is turned and over the lower stone. The juice is pressed out and flows by openings in the base to a holder the outlet of which is closed. The cane is then brought to another place. Here it is put into baskets of plaited reeds, which are split open below and at the sides. They are laid under the wheel of a beam and by means of the beam the wheel rolls on them till it has crushed them and the rest of the juice has been pressed out."

There is yet one more appliance which came to be adapted to the expression of the juice from the cane and that is the beam press, a description of which, as used in the Eighteenth Century in Spain, and probably of much earlier introduction, reads:—"After the canes have passed through the cylinders they are thrown into a wooden vat well hooped with iron and placed over a cistern to receive the juice from the second pressure. Large beams are placed lengthwise upon each other and fastened together with ropes. A round board the size of the vat is laid on the canes upon which the lever presses and squeezes out the last drop of juice."

All the appliances described had been invented for other purposes. We now pass on to deal with the roller mill, the invention of which, as regards western practice, can be definitely fixed as in the middle of the Fifteenth Century. When, however, the types of roller mills used in India first appeared cannot be stated. Of the operation of the two-roller cattle-driven mill, which we think derives from the Persian water wheel, there is definite mention in Spain in the mid-Eighteenth Century, and it may be of much earlier origin.

The three-roller mill, whence the modern cane mill descends, was invented for the specific purpose of treating canes in 1449 by Pietro Speciale, Prefect of Sicily, who "had planted with honey canes the delightful country of the Ficarazzi, where he had an estate, and there he was the first to make that wonderful machine that the Sicilians call a Trapetto for extracting the sugar." This device was a vertical three-roller mill with power applied to the central element, which geared with the two outer rollers. For three hundred and fifty years it remained the means by which almost the whole of the world's supply of sugar was obtained.

We have made an extensive search for any record of a roller mill of any form earlier than that devised by Speciale and have found no mention of one. It would seem, then, that to Speciale is to be given the credit of having originated a master invention, used not only in the sugar but in many other industries. Of these can be immediately called to mind flour milling, metal-plate rolling, ore crushing and numerous examples in the textile and paper industries. While it is not pretended that all these derive directly from the mill of Speciale, yet when reduced to the lowest common denominator the principle of their operation remains the same.

The mills to which attention has so far been called were all made of wood. The first mention of the use of iron is in Ligon, in 1647. Very soon afterwards appears the first record of iron rollers, constructed as hollow shells to cover the wooden core. The first maker of these was almost certainly George Sitwell, of Renishaw, who was operating furnaces and forges near Derby in 1652. In 1663, he sent to London a "specimen roller of every sort with a pack thread of height and compass." This method continued for a long time, as in Patent No. 433, granted to William Harding in 1721, occur these words:—". . . . sugar mills . . . being made with large timber and wooden coggs, only having a case of iron on the timber and an iron gudgeon through them. . . . Now models have been made of sugar mills, engines, and wormes whereof the rollers, coggs and gudgeons are all iron . . . ." These rollers were hollow and cast in one piece with the gudgeon, which was attached to the shell by a spider. This method of construction had not been entirely abandoned as late as 1845.

In the modern sugar mill the rolls are horizontal and their centres are located at the angles of an isosceles triangle, in which position they are secured in a housing or headstock. The earliest record of this design is to be found in a drawing of 1754, made by John Smeaton for a Mr. Grey, of Jamaica. It is marked "not executed." In this design the rollers rest on surfaces at right angles to the lines joining the centres of the top and lower rollers. This feature, though it has much to recommend it, is but seldom found in modern practice.

The first mill with horizontal rollers located with their centres at the angles of an isosceles triangle was made in 1794 by John Collinge, an axletree maker of Lambeth. There is no record to show of what his design consisted, but it is probable that the use of timber continued to enter into the design of the headstock. The adoption of this arrangement was rapid. The order book of Messrs. Fawcett, Preston and Company, of Liverpool, for the years 1813-17, contains orders for 63 horizontal and only 11 vertical mills. To Mauritius the first mill of this type went in 1819 to the order of Charles Telfair, for Bel Ombre estate. When once the triangular arrangement of the rollers had been adopted the cane mill had received substantially its present form. The changes in the next 50 years were concerned mainly in the reduction of the form of the headstock to a sound engineering model. A mill built about 1825, by Jukes and Coulson, of London, is of all-iron construction, but with the rollers still made as hollow shells. The headstock consists essentially of a central pillar and two outer pillars, with the outer rollers resting on surfaces in the gaps between the outer and central pillar, which itself sustains the top or driven roller. The holding-down bolts and the adjusting screws remain in use in the present-day model. The side pillars, which take up the side thrust of the lower rollers, formed a weak point in the design of the Jukes and Coulson mill. The next step was to tie together the central and outer pillars by rods. The shape of the headstock also became modified and began to approach that of the modern mill. This design is found in drawings in the Boulton and Watt Collection in the Birmingham Reference Library and seems to have become standard practice about 1830.

The modern form of headstock appears first in a mill due to Buchanan, patent No. 1574 of 1858. It forms what is referred to as the open-side gap type of headstock, which permits the two lower rollers to be withdrawn by sliding. While this design has become standardised, the arrangement appears only as a subsidiary claim in the patent, the major claim relating to the construction of the headstock of wrought-iron plates bolted together in place of a one-piece casting; this method of construction has never been brought into use. What are now known as the side roller caps appear in this patent as wrought-iron tie bars. The side thrust of the lower rollers is thus removed from the cast-iron headstock and this arrangement, acting in combination with the open-side gap headstock, made a notable step forward in design.

The three-roller mill was finally reduced to its present form by Théophile Rousselot, a Martinique engineer. As shown in patent No. 790 of 1871, he retained the open-side gaps of Buchanan, making the headstocks of cast iron, and substituting cast-iron side caps for Buchanan's wrought-iron tie bars. He strengthened the headstocks by fitting two flat tie bars on each side. Links or transverse bars in horizontal recesses in the outer faces of the side caps connected the ends of the upper and lower pairs of tie bars. His essential patent claims, which cover what are still called "Rousselot bolts," read:—"Secondly. Securing the double bearings of the two lower rollers by means of horizontal ties, as described and shown." "Thirdly. Arranging the said ties so that they maintain all the pressure arising from the squeezing of the canes, as described and shown." This design passed into immediate acceptance, but, later, round bars screwed at each end, and passing through cored holes in the headstocks and side caps, were substituted for the flat tie bars, and these round bars remain as routine and standard design.

In the operation of the three-roller mill, as invented by Speciale, it was necessary to direct by hand the once-crushed material to the second bite between the central and the last outer roller. The older literature of the West Indies contains many references to the frequency of accidents, so much so that it was customary to keep a cutlass at the mill so as to be able to chop off the arm of any hapless negro who might get caught. In the mill of Collinge, hand-feeding of the cane to the second bite was also practised until, in 1805, a Barbados planter, Bell, added an appliance consisting of a substantial beam with curved upper surface to direct the partially-crushed material to the second bite. This contrivance is called the dumb-turner, said to be so named in contradistinction to the volubility of the negresses who previously had done this work. As originally made, the dumb-turner was carried in windows arranged in the headstocks, and adjustment was laboriously made by the insertion of shims. The first approach to the modern form appears in Sir William Rennie Watson's patent, No. 1606 of 1871,

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the patent reading:—"Fixing the dumb turner in slides and connecting it by bolts or slides to the caps of the bearings of one of the lower rollers, in order to maintain its position relatively with the said roller constant." Watson's dumb-turner was a comparatively light beam, which would have had to have been discarded when worn. It is now made in two parts, the dumb-turner to which is bolted the trash-plate, the correct curve for which has been the subject of much controversy.

In the mills which were first built, the rollers were held in rigid frames that allowed no movement to any element. This rigidity was disadvantageous for two reasons: With a feed lighter than the regular, the extraction of juice suffered, and any excess feed was likely to cause a fracture of the framework or of the mill gudgeon. Indeed, with a rigid mill and a fixed setting, it was necessary in order to obtain good results to regulate within narrow limits the quantity of fibre passed in a unit of time. The first device admitting of elasticity to the system is to be found in a drawing in the Boulton and Watt Collection in the Birmingham Reference Library and is of date about 1830. It shows a two-roller mill, the upper element of which is free to move under the control of a pressure obtained by means of a weight and lever. A similar device, but acting on the side rollers, is recorded as in use in Demerara in 1858, and as being the invention of an engineer, Moore. The system again appears as late as 1890 in U.S. Patent No. 422,289, granted to Brullard. These devices never received any extended application.

Almost without exception, cane mills are now constructed with the top roller free to move against the pressure obtained from a hydraulic accumulator. The first application of this means is indicated in U.S. Patent No. 21,340 (1858), granted to Jeremiah Howard. In this patent, the drawing of which is little more than diagrammatic, the position of the back lower roller was controlled by the pressure exerted by a pump worked off the top roller of the mill, a valve permitting the escape of the water at a pre-determined pressure. There is no record of the operation of this device, and it was not till 1871-72 that two inventions appeared, one British and one American, which made operation of cane mills under an elastic fluid control practicable. The first of these patents was that of Duncan Stewart, No. 3269 of 1871. His preferred arrangement shows rams, controlled by hydraulic pressure derived from an accumulator, supporting and acting on the brasses in which the lower rollers rotate. Both front and back rollers rest on surfaces at right angles to the lines adjoining the centres of these rollers to that of the top roller. The resemblance of this arrangement to that of Smeaton is at once apparent. The second of these patents is that of John McDonald, United States, No. 128,235, taken out in 1872. It differs from that of Stewart in the selection of the top roller as the movable element, with the pressure acting on the top brass through the holding-down bolts.

The modern mill embodies the open-side gap headstock of Buchanan, the horizontal throughway bolts of Rousselot, the adjustable trash-turner of Watson, and the hydraulic control of Stewart and McDonald. The three improvements last mentioned all appeared in 1871-72. Developments since then have been in detail and not in principle. Of these may be mentioned the inclined holding-down bolts of Chapman, Patent No. 10,469 of 1894, designed to diminish the width of the trash-plate; and the breech-block type of hydraulic ram, located in the top cap and bearing on the top roller, which is now almost always selected as the movable element. In the last few years, mills have been constructed with all-steel headstocks combined with the elimination of both holding-down and Rousselot bolts. Exceptionally, mills are found with the hydraulic regulators acting on the lower rollers and conforming to the preferred arrangement of Duncan Stewart.

The Fabrication of Lead-Bearing Steels.—In a recent issue of *Metal Progress*, Messrs. J. W. Halley and K. D. Martin give an account of investigations made in order to determine whether lead, in dangerous amounts, is released into the atmosphere when lead-bearing steels, containing 0·25 per cent. of lead, are welded, cut or forged. Their results indicate that there is no danger to the health of the workers in the handling, machining, heat-treating and ordinary forging of the material. When, however, the steel is welded or flame-cut, the authors state that care should be taken that the amount of lead which may be released into the air does not exceed a safe limit, which they place at 3 milligrammes of lead in 10 cub. m. of air. In this connection it is pointed out that the equipment for providing additional ventilation, in cases in which this is deemed necessary, should be relatively inexpensive.

"ENGINEERING" ILLUSTRATED PATENT RECORD.

ABSTRACTS OF SPECIFICATIONS RECENTLY PUBLISHED UNDER THE ACTS OF 1907 TO 1939.

The number of views given in the Specification Drawings is stated in each case; where none is mentioned, the Specification is not illustrated.
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Any person may, at any time within two months from the date of the advertisement of the acceptance of a Complete Specification, give notice at the Patent Office of opposition to the grant of a Patent on any of the grounds mentioned in the Acts.

AERONAUTICS.

523,332. De-Icer for Aircraft. V.D.M. Spinners, Limited, of Warwick, R. McGlasson, and F. G. Marshall, of Leamington Spa. (3 *Figs.*) December 31, 1938.—The de-icer is entirely automatic in operation, being controlled by the temperature of the surrounding atmosphere. A closed container *d* for the anti-freeze solution is fixed around the inside of the forward part of the spinner, the contour of which it follows. For each blade *c* of the air-screw, the container is provided with a valve *e* (Fig. 2) of the piston type. The valve cylinder is closed at each end, except for an air-vent at the bottom, and has inlet and outlet ports f^1, f^2, communicating respectively with the interior of the container *d* and with a chamber *h* fixed to the inside wall of the spinner in front of the blade. The chamber is provided with a number of delivery orifices through which the anti-freeze is ejected when the spinner is rotating and the valve is

Fig. 1.

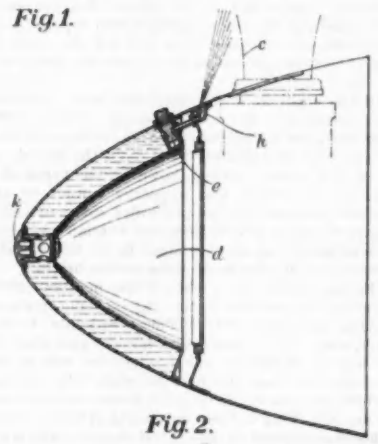

Fig. 2.

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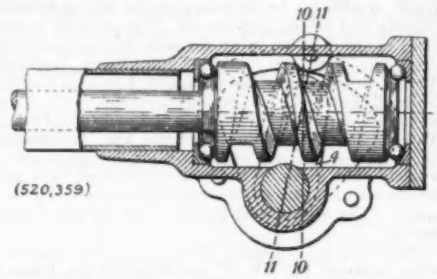
open. The outer end of the valve cylinder is filled with mercury above the valve. During rotation of the spinner, centrifugal force keeps the valve in close contact with the mercury and so long as the atmospheric temperature is relatively high the valve remains closed. When, however, during flight, the atmospheric temperature falls below, say, 15 deg. to 25 deg. F., the resulting contraction of the mercury allows the valve to move out under the action of centrifugal force to connect the inlet and outlet ports. The centrifugal force on the anti-freeze solution in the container then causes jets of anti-freeze to be sprayed in front of each blade, some of the spray being distributed to other parts of the machine, such as the wings, by the action of the slip stream. The container has a filling orifice *k* at the nose of the spinner. Baffle plates inside the container counteract any tendency of the solution to swirl and so produce out of balance conditions of the spinner and airscrew during flight. (*Accepted July* 11, 1940.)

MOTOR VEHICLES.

520,359. Steering Gear. R. Bishop, of Golders Green, and R. H. Johnston, of Westminster. (2 *Figs.*) October 29, 1938.—The gear is of the kind employing a worm-thread cam which drives a follower arm. Hitherto it has been usual to arrange that, in the straight-ahead position of the wheels, the arm is in its mid-position, where it is at right angles to the axis of the worm. Due, however, to the pitch angle of the worm thread, the leverage at the mid-position is not a maximum, the position for this value lying to one side of the mid-position, so that a greater effort is required to operate the gear in one direction than in the other. In the present invention the axis of the rocker arm 4 is, in its mid-position, displaced from the normal line 10 to the line 11, the angle between the lines 11 and 10 being equal to the pitch angle of the thread of the worm at the point of contact of the cam and follower. The result is that



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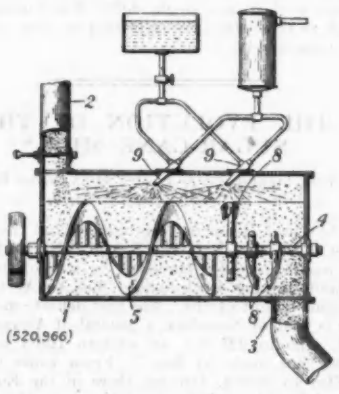
equal efforts are required to move the rocker arm 4 through equal angles on opposite sides of its mid-position. The new form of cam has less variation in the thickness of the lands from one end to the other, thus reducing the danger of distortion during hardening, and permitting the use of greater gear ratios, since the lands at the end of the worm are not so thin as before. (*Accepted April* 22, 1940.)

MISCELLANEOUS.

520,966. Meal-Moistening Machine. T. S. Kelsey, Limited, of London, and A. F. Weber, of London. (2 *Figs.*) November 4, 1938.—The machine is used for adding water to meals intended for animal foods or improvers to flour for human consumption. Difficulty has been experienced with previous machines in obtaining a thorough uniform distribution of the moisture throughout the meal. This machine consists of a chamber 1, the lower part of which is a trough of semi-circular cross-section. The top of the chamber is considerably more than the radius of the trough above its axis. A spout 2 leading from the mixers for mixing the ingredients of the meal delivers the dry meal at one end of the chamber through the top and a conduit 3 discharges it from the bottom of the trough at the other end to a packing location, at which it is filled into sacks. A shaft 4 carries a helical blade 5, which rotates close to the curved wall of the trough. The blade 5 is comparatively narrow and supported from the shaft by radial arms, and when rotated it feeds the meal through the chamber to the outlet. The axial length of the blade 5 is about two-thirds of the length of the chamber, and the remaining portion of the shaft 4 carries three radial arms to which are secured beater blades 8. These blades 8 are com-



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paratively narrow and arranged helically at a smaller pitch than that of the blade 5. Atomising nozzles 9 project through the top of the chamber and deliver a fine mist of water into the upper part. The nozzles are supplied with water and compressed air. The flow of meal into the chamber is accurately controlled by a calibrated slide, which can be adjusted across the spout. In operation, the shaft and blades are rotated at 400 r.p.m. to 500 r.p.m. The helical blade 5 feeds the meal along the trough, agitating it violently on the way by centrifugal action, into the sphere of action of the beater blades 8, which more violently agitate the meal. The result is to distribute it in the form of a cloud of fine particles throughout the full length and cross section of the chamber. The particles are thereby brought into intimate contact with the extremely fine particles of water distributed throughout the upper part of the chamber and flow out continuously through the discharge conduit 3. It is found that the moisture is evenly distributed throughout the meal as a result of the combination of the centrifugal action of the blades and the force of the compressed air through the atomising jets. (*Accepted May* 8, 1940.)